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ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Alfred Harker, M.A., LL.D. (McGill), F.R.S., President of the Geological Society of London 1916–17, Fellow of St. John's College, and Lecturer in Petrology in the University of Cambridge.

(WITH A PORTRAIT, PLATE XVIII.)

DR. ALFRED HARKER was born at Hull, in Yorkshire, on February 19, 1859; his name may thus be appropriately added, as an "eminent geologist", to the county which claims amongst its sons the name of Sedgwick, the Woodwardian Professor of Geology in the University of Cambridge (1818–73), the first who taught modern geology; and famous as having had such historians as William Smith (the "Father of English Geology") and his nephew, Professor John Phillips; also as the birthplace of Sorby, Williamson, Strickland, Hudleston, and many others.

He had, as a boy, a taste for chemistry and natural history, and made his first acquaintance with geology in his holiday wanderings along the Yorkshire coast, with John Phillips' writings as his guide.

It was as a student of mathematics that Harker went up to Cambridge, and was entered at St. John's College in 1878. But he soon found, in the genial Professor McKenny Hughes,[1] one who was ever ready to welcome any "freshman" with geological leanings, and Harker became one of the first members of the Sedgwick Club, founded about that time by Watts and others of his contemporaries.

After graduating in the Mathematical Tripos as 8th Wrangler, in January, 1882, Harker came back to geology by way of physics and mineralogy, and was at once offered a teaching post on the geological staff. As demonstrator and afterwards lecturer, he has been responsible for the teaching of petrology at Cambridge for more than thirty years; but for a long time the almost total want of accommodation and equipment in the old Woodwardian Museum made it impossible to carry out this work in a satisfactory manner.

Alfred Harker was elected a Fellow of St. John's in 1885. In those days this College, owing doubtless in part to Professor Bonney's influence, was notably strong in Geology. Of the last nine Presidents of the Geological Society five have been Johnians.

As a field-geologist his earliest original work was done in North

[1] Written on May 10. Our dear friend Professor Hughes passed away on June 9; see Obituary Notice, p. 334.—Ed. Geol. Mag.

Wales, first on the cleavage structure of the slates, and then on the Ordovician igneous rocks. The results of the latter work were in part embodied in the Sedgwick Prize Essay for 1888.

From 1889 to 1893, excepting a visit to America, Harker's vacations were spent mostly with his friend and fellow-Johnian, J. E. Marr, in the Lake District. Their aim was principally to decipher the geological structure and sequence of that district in the light of what had been learnt in other disturbed areas. This problem is perhaps not to be finally solved without a complete re-survey of the ground; but some conclusions were reached, and memoirs on the Shap granite and its metamorphism and on the Carrock Fell intrusions were also among the results of those pleasant years.

In 1895, by the good offices of Sir Archibald Geikie, Harker became attached to the Geological Survey of Scotland, and was engaged for ten years in the investigation of part of Skye and of the Small Isles to the south. The summer half of the year was spent in mapping and the winter half in the study of material gathered in the field. The results of this work are contained in the official maps and memoirs, including a special memoir on *The Tertiary Igneous Rocks of Skye*.

In 1905 he quitted the Geological Survey for other engagements. The geological department at Cambridge was now housed in the new Sedgwick Museum, and teaching duties, together with the charge of the petrological section of the Museum, had become more engrossing. Dr. Harker found time, however, for frequent visits to the Highlands and other parts of Britain with occasional excursions abroad. He had made it part of his programme as a teacher of students to bring together, as far as possible, complete representative collections of rock-specimens in the Museum at Cambridge, which now possesses large series from many British areas, as well as from Norway, Canada, and other countries. The collection of rock-slices also has grown until it now numbers more than 12,000.

Dr. Harker had written in 1895, chiefly to meet the needs of his own students, a Textbook of Petrography, and this has been revised from time to time in subsequent editions. In 1909 appeared *The Natural History of Igneous Rocks*, which aimed especially at interesting geologists in the genetic aspect of petrology.

In February, 1907, on the occasion of his presenting the Murchison Medal to Mr. Alfred Harker, F.R.S., Sir Archibald Geikie, then President of the Geological Society, said: "The Murchison Medal has been assigned to you as a testimony of the Council's appreciation of the importance of your contributions to Petrographical and Structural Geology.

"You had already distinguished yourself by your studies in cleavage, by the zeal and success with which you had thrown yourself into the pursuit of petrographical research along those modern paths in which this department of our science has been so transformed and enlarged, and lastly by the skill which you had shown in the field investigation of the ancient igneous rocks of North Wales and of part of the Lake District.

"With this reputation already established and yearly growing, you were induced, at my request, to enter the Geological Survey. Although the circumstances under which you joined that service formed a new departure in its usages, I have always felt that on no part of my long connection with the Survey could I look back with more satisfaction than on the arrangements which enabled us to secure your services.

"You speedily acquired the skill of a practised surveyor, and among the hills of Skye and Rum you had an opportunity of mapping some of the most complicated and deeply interesting pieces of volcanic geology in this country. Having had from time to time opportunities of visiting you on the ground, I can bear witness both to the bodily vigour and endurance and to the geological enthusiasm and insight with which you climbed crags and peaks on which no geologist had set foot before you. The maps and memoirs which you have produced of these portions of the Inner Hebrides will always remain as a monument of your prowess as a field geologist and petrographer."

Another of his fellow-workers writes: "What specially struck me about Harker was his thoroughness. Having started on a piece of work he devoted his whole energy to its completion. All else was subordinated to its execution, and one might almost literally say that no stone was left unturned which would cast any light upon it."

"He is one of those who believe that for the right understanding of a science it is necessary to know something of the history of its growth, and with this in view he has accumulated in his library a valuable series of works which bear upon the early history of the science of geology and the more recent branch of petrography.

"Harker's time has been largely occupied by teaching and research, but he has nevertheless contrived to devote much of it to the enrichment of the petrographical collections in the Sedgwick Museum, and to their arrangement. He has travelled much to obtain specimens for this purpose. Of special interest are two magnificent collections which he has brought together to illustrate genetic connexion of igneous rocks, the one of those of Western Scotland, the other of the group rendered classic by the researches of Brögger in the Christiania region.

"Though Harker's fame rests largely on his petrographical work he is also a physical geologist of a very high order, as might be expected from one who prefaced his geological career by a mathematical training. We may make special mention of the very important contribution which he made to the physics of glacial erosion in his paper on Ice Erosion in the Cuillin Hills (Skye), which appeared in the Transactions of the Royal Society of Edinburgh, 1901 (T.R.S.E., vol. xl, pt. ii)."

In addition to his service to science, as a Lecturer in Petrology in the University, Dr. Harker has published most of the results of his investigations, whether in the field, the laboratory, or with the microscope, in a permanent form, for the use of geologists generally; and the Editor is happy to record that, of his numerous publications, fifty are preserved in the pages of the Geological Magazine.

Dr. Harker received the Wollaston Donation Fund, 1896; the Murchison Medal, 1907. He was President of Section C, British Association, at Portsmouth, 1911. He has also kept up connexion with his native county, and was President of the Yorkshire Naturalists' Union, 1911, and President of the Yorkshire Geological Society, 1912–13. The McGill University (Montreal) conferred on Dr. Harker the honorary degree of LL.D. in 1913. He is at this time President of the Geological Society of London, 1916–17, till February, 1918.

List of Dr. A. Harker's principal Geological Writings.

1884. "Graphical Methods in Field Geology": Geol. Mag., pp. 154–62.
1885. "The Oolites of the Cave District": *Naturalist*, pp. 229–32.
"The Cause of Slaty Cleavage": Geol. Mag., pp. 15–17.
"On the Successive Stages of Slaty Cleavage": ibid., pp. 266–8.
1886. "Report on Slaty Cleavage and Allied Rock Structures": Rep. Brit. Assoc. for 1885, pp. 813–52.
1887. "On some Anglesey Dykes," I and II: Geol. Mag., pp. 409–16, 546–52.
1888. "Notes on the Geology of Mynydd Mawr and the Nantlle Valley": ibid., pp. 221–6.
"On some Anglesey Dykes," III: ibid., pp. 267–72.
"Additional Note on the Blue Hornblende of Mynydd Mawr": ibid., pp. 455–6.
"On the Eruptive Rocks of the Neighbourhood of Sarn, Caernarvonshire": Q.J.G.S., vol. xliv, pp. 442–61.
1889. "Notes on the Physics of Metamorphism": Geol. Mag., pp. 15–20.
"Local Thickening of Dykes and Beds by Folding": ibid., pp. 69–70.
"Eyes of Pyrites and other Minerals in Slate": ibid., pp. 396–7.
The Bala Volcanic Series of Caernarvonshire (Sedgwick Prize Essay for 1888), 8vo, Cambridge.
"Petrological Notes on Boulders from the Boulder-Clays of East Yorkshire": Proc. Yorks. Geol. Soc., vol. xi, pp. 300–7.
1890. "Petrological Notes on Some of the Larger Boulders on the Beach South of Flamborough Head": ibid., pp. 409–23.
1891. "The Ancient Lavas of the English Lake District": *Naturalist*, pp. 145–7.
"Notes on a Collection of Rocks from the Tonga Islands": Geol. Mag., pp. 250–8.
(With J. E. Marr.) "The Shap Granite and the Associated Igneous and Metamorphic Rocks": Q.J.G.S., vol. xlvii, pp. 266–327.
"Petrological Notes on Rocks from the Cross Fell Inlier": ibid., pp. 512–25.
"Thermo-metamorphism in Igneous Rocks": Bul. Geol. Soc. Amer., vol. iii, pp. 16–22.
1892. "Physical Geology in the Basin of the Colorado": *Natural Science*, vol. i, pp. 205–10.
"The Lamprophyres of the North of England": Geol. Mag., pp. 199–206.
"Porphyritic Quartz in Basic Igneous Rocks": ibid., pp. 485–8.
1893. "Norwegian Boulders in Holderness": *Naturalist*, pp. 1–4.
"The Use of the Protractor in Field Geology": Sci. Proc. Roy. Dubl. Soc. (N.S.), vol. viii, pp. 12–20.
(With J. E. Marr.) "Supplementary Notes on the Metamorphic Rocks around the Shap Granite": Q.J.G.S., vol. xlix, pp. 359–71.
"On the Migration of Material during Thermal Metamorphism": *Journ. Geol.*, vol. i, pp. 574–8.
"Extinction Angles in Cleavage-Flakes": *Min. Mag.*, vol. x, pp. 239–40.
"Berthelot's Principle applied to Magmatic Concentration": Geol. Mag., pp. 546–7.

1894. "Carrock Fell: a Study in the Variation of Igneous Rocks," I: Q.J.G.S., vol. l, pp. 311–36.
"The Evolution of Igneous Rocks": *Science Progress*, vol. i, pp. 152–5.
"Ancient Volcanic Rocks": ibid., vol. ii, pp. 48–63.
"Cordierite in the Lake District": Geol. Mag., pp. 169–70.
"On some Variolitic Rocks on Carrock Fell": ibid., pp. 551–3.

1895. "Carrock Fell: a Study in the Variation of Igneous Rocks," II and III: Q.J.G.S., vol. li, pp. 125–47.
Petrology for Students: an Introduction to the Study of Rocks under the Microscope, 8vo, Cambridge. (Revised editions in 1897, 1902, and 1908, and French translation in 1902.)

1896. "On certain Granophyres, modified by the Incorporation of Gabbro Fragments, in Strath (Skye)": Q.J.G.S., vol. lii, pp. 320–8.
"The Natural History of Igneous Rocks. I. Their Geographical and Chronological Distribution": *Science Progress* (N.S.), vol. i, pp. 12–33.

1898. "The Natural History of Igneous Rocks. II. Their Forms and Habits": ibid., vol. ii, pp. 203–18.

1899. "Glaciated Valleys in the Cuillins, Skye": Geol. Mag., pp. 196–9.
"On the Average Composition of British Igneous Rocks": ibid., pp. 220–2.
"Notes on Subaërial Erosion in the Isle of Skye": ibid., pp. 485–91.
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1900. "Magnetic Disturbances in the Isle of Skye": Proc. Camb. Phil. Soc., vol. x, pp. 268–78.
"Igneous Rock-Series and Mixed Igneous Rocks": *Journ. Geol.*, vol. viii, pp. 389–99.

1901. "On a Question Relative to Extinction-Angles in Rock-Slices": *Min. Mag.*, vol. xiii, pp. 66–8.
"Ice-Erosion in the Cuillin Hills, Skye": Trans. Roy. Soc. Edin., vol. xl, pp. 221–52.
"The Sequence of the Tertiary Igneous Rocks of Skye": Geol. Mag., pp. 506–9.

1903. "The Overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses": Q.J.G.S., vol. lix, pp. 189–215.

1904. (With C. T. Clough.) *The Geology of West Central Skye, with Soay* (Mem. Geol. Surv. Scot.).
(With notes by C. T. Clough.) *The Tertiary Igneous Rocks of Skye* (Mem. Geol. Surv. U.K.).

1905. "The Tertiary Crust-Movements of the Inner Hebrides": Trans. Edin. Geol. Soc., vol. viii, pp. 344–50.

1906. "The Geological Structure of the Sgùrr of Eigg": Q.J.G.S., vol. lxii, pp. 40–67.
"Cordierite in the Metamorphosed Skiddaw Slates": *Naturalist*, pp. 121–3.
"A Cordierite-bearing Lava from the Lake District": Geol. Mag., pp. 176–7.

1907. "Notes on the Rocks of the *Beagle* Collection," I: ibid., pp. 100–6.
"Igneous Rock-magmas as Solutions": *Science Progress*, vol. ii, pp. 239–54.

1908. (With contributions by G. Barrow.) *The Geology of the Small Isles of Inverness-shire* (Mem. Geol. Surv. Scot.).

1909. *The Natural History of Igneous Rocks*, 8vo, London.

1910. *Tables for Calculation of Rock Analyses*, Cambridge.

1912. Presidential Address to Section C (Geology): Rep. Brit. Assoc. for 1911, pp. 370–81.
"Petrology in Yorkshire" (Presidential Address to the Yorkshire Naturalists' Union): *Naturalist*, pp. 37–44, 69–73.

1912. "Lamprophyre Dykes in Long Sleddale": ibid., pp. 266–7.
1914. "Fractional Crystallization the Prime Factor in the Differentiation of Rock-magmas": Congr. Géol. Int. Comp.-Rend., xii, pp. 205–8.
"The Sgürr of Eigg: some Comments on Mr. Bailey's Paper": Geol. Mag., pp. 306–8.
"Some Remarks on Geology in Relation to the Exact Sciences, with an Excursus on Geological Time" (Presidential Address to the Yorkshire Geological Society): Proc. Yorks. Geol. Soc., vol. xix, pp. 1–13.
1916. "Differentiation in Intercrustal Magma-Basins": *Journ. Geol.*, vol. xxiv, pp. 554–8.
1917. Presidential Address to the Geological Society of London, delivered February 16 (see Reports and Proceedings, Geol. Mag., pp. 191–2, April, 1917).

II.—Cretaceous Mollusca from New Zealand.

By C. T. Trechmann, M.Sc., F.G.S.

PLATES XIX AND XX.[1]

Introduction.

OWING to incomplete palæontological knowledge, the true age and correlation of the various divisions of the great Mesozoic series of New Zealand, which, together with the Maitai Series, forms such an important element in the structure of the country, has long remained a matter of uncertainty. In consequence the idea has to some extent taken hold among New Zealand geologists that the Mesozoic faunas, owing to supposed conditions of isolation, show archaic features. It was explained that certain Permian forms occurred in the Trias and that Trias forms may have persisted into Jurassic times, and to a still greater extent that a Cretaceous fauna lived on in this portion of the earth into the Tertiary period.

On going further into these questions I find no support for the theory, and in the case of the Cretaceous, a comparison of the fauna of the Senonian with corresponding faunas of Australia and especially of South America shows that the isolated survival theory is untenable. The arguments adduced in its favour apply equally well to the Cretaceous of South America and other parts of the Indo-Pacific region as they do to New Zealand.

It must be remembered that the present isolation of New Zealand as a land mass is a phenomenon of late geological time. In the Permo-Carboniferous period there was as much or more land in the Southern Hemisphere as there now is in the Northern. The Cretaceous and Tertiary faunas of New Zealand point to a much closer connexion with South America than obtains at the present day. The number of species of recent Mollusca common to the coasts of New Zealand and Tierra del Fuego is now very slight.

In a paper recently published in this Magazine[2] I showed that the Maitai Series contains a fauna which agrees, so far as it goes, exactly with that of the marine Permo-Carboniferous of New South Wales

[1] Plate XXI will appear with the second part in the August Number.

[2] "The Age of the Maitai Series of New Zealand": Geol. Mag., N.S., Dec. VI, Vol. IV, pp. 53–64, Feb. 1917.

and Tasmania, but that the Maitai beds differ from the Permo-Carboniferous of Gondwanaland in being entirely marine.

I also showed in a recent communication to the Geological Society that the Kaihiku, the lowest known Mesozoic fossil-bearing horizon in New Zealand, contains fossils of late Middle or early Upper Trias, and is not as was formerly supposed of Permian age, and that the Carnic, Noric, and Rhætic horizons of the Upper Trias are well represented.

The Jurassic still remains the greatest *terra incognita* in New Zealand palæontology, and owing to the discontinuous nature of the outcrops, the scarcity and indifferent state of preservation of the fossils, its study will involve some difficulty. Several horizons seem to be represented by the fossils, of which I have a considerable collection. A knowledge of the Jurassic horizons which occur in New Zealand is an important matter, because the determination of the highest Jurassic and the lowest Cretaceous beds will indicate the time limits during which New Zealand first became a land surface.

It now seems to me quite clear that the New Zealand continent, and the present New Zealand is the relic of a former land mass both of continental dimensions and of continental faunal character, originated some time about the period of the final fragmentation of Gondwanaland. I am also inclined to think that its compression and uplift are among the phenomena of readjustment consequent upon that event.

The Cretaceous rocks form the basal portion of the newer or covering series, and where they occur they rest, as in Chili and the Californian coast ranges, with a most pronounced unconformity on the denuded edges of the folded and in part metamorphosed rocks beneath them. The lowest Cretaceous marine horizon present will afford us knowledge when the sea began once more to transgress upon the margins of the old peneplaned and lowered land mass which had arisen and been partly denuded during the period intervening, so far as we know at present, between very late Jurassic and Upper Cretaceous times.

The outcrops of the Upper Cretaceous beds in New Zealand are well shown by Professor J. Park on a small-scale map.[1]

They occur in six or seven more or less isolated patches of greater or less extent. The relations of the Cretaceous to the overlying Tertiary series have given rise to much discussion, into which however I do not propose to enter in the present paper.

On the eastern side of the Alpine chain in the middle part of the South Island, in the Waimakariri and Waipara gorges, the marine Upper Senonian rests on the upturned edges of the older rocks. This condition of things obtains also at Quiriquina, on the coast of Chili. In the north-eastern part of the South Island and apparently also on the eastern side of the North Island some earlier Cretaceous beds with *Inoceramus* occur. In this connexion it is important to notice that in South Patagonia, between Lago Argentino and Last Hope Inlet, on the eastern side of the Cordillera, the Upper Senonian rests on beds containing *Inoceramus Steinmanni*,

[1] *The Geology of New Zealand*, 1910, sketch-map.

Wilckens, which are Upper Cretaceous but probably still of Senonian age.

The faunal and stratigraphical details in New Zealand still remain to be worked out, especially in the North Island, but the facts already known point to a north to south as well as to an east to west transgression of late Cretaceous beds, with a further overstep of the Upper Senonian to the south-west across the earlier upper Cretaceous beds beneath them. Mr. H. Woods has recently examined some Cretaceous fossils belonging to the New Zealand Survey collections and concludes that two distinct faunas occur.[1] The older of these occurs at Coverham, in the middle Clarence Valley in the north-east corner of the South Island, and is of approximately Upper Greensand or Gault age. The younger fauna of Upper Senonian age occurs at Amuri Bluff on the north-east coast of the South Island, at Selwyn Rapids, and other localities.

I understand that only the Lamellibranchs of Selwyn Rapids were examined by Mr. Woods. His work, however, is not published yet. Professor P. Marshall has recently investigated a very interesting and rather extensive fauna which occurs at Wangaloa, on the south-east coast of the South Island south of Dunedin. It is clearly newer than the Upper Senonian faunas above-mentioned, but must, on account of the presence of *Pugnellus*, in my opinion, still be referred to the Cretaceous. I should regard it as Danian or Maestrichtian.

The object of the present paper is to describe a series of fossils other than the groups already described by Mr. Woods or those at present under description by Professor Marshall, which throw further light on the age and correlation of some of the Cretaceous beds of the South Island of New Zealand.

All the specimens described were collected by myself, so I can guarantee the accuracy of the localities and horizons.

The Localities.

Selwyn Rapids.

This locality is situated at the base of the eastern foothills of the Southern Alps about 36 miles west of Christchurch. The railway station is Glentunnel, and the outcrop forms a series of rapids in the Selwyn River about a mile from the station. The beds consist of a series of glauconitic greensands more or less concretionary. In the bed of a tributary creek a few hundred yards away there are several enormous spherical concretions[2] 5 or 6 feet in diameter

[1] *Nature*, March 22, 1917, p. 79.

[2] Similar concretions occur at Hampden, in North Otago, in beds apparently of the same age that crop out on the seashore. The concretions are surrounded by a casing of stony material in which the finest cone-in-cone structure I have ever seen is developed. The apices of the cones as a rule are directed towards the centre of the nodule, and the bases of the cones on the outside assume forms that suggest floral structures. The outer skin of the septaria is a few inches thick and is generally loose and detached from the concretion and is easily broken off. This together with the presence of yellow calcite veins which pass in all directions through the septaria suggests that the cone-in-cone structure is connected with a contraction of the inner portion of the septarian concretions. These large septarian nodules are rather sparingly distributed in

that show sections of *Conchothyra* and other fossils on the weathered surfaces. These concretions are extremely hard in places.

At the Rapids the fossils are very badly preserved in the softer rock, but the harder portions exhibit many sections of well-preserved fossils on the waterworn surface, but the rock is so hard that a hammer and chisel are of little use. On one visit, however, I employed a man to put some half-dozen shots of gelignite into the most likely-looking places, with the result that a large quantity of rock was broken up and became available for collecting.

The fossils show some unequal distribution in this bed, and *Conchothyra*, *Aplustrum*, and other forms occur in little clusters or nests. Lamellibranchs and Gasteropods are the chief fossils, but scales and bones of fish also occur, the former rather plentifully. I was fortunate in obtaining two Ammonites and a Belemnite, neither of which seems to have previously been recorded from this locality, and which establish the Mesozoic age of the beds beyond question. I collected a large number of Lamellibranchs, but as Mr. Woods has described those of the old Survey collection from this locality I await the appearance of his memoir before I describe them or record any new forms there may be among them.

Waipara Gorge.

In the Waipara Gorge, about 35 miles north of Christchurch, there is a glauconitic sandstone full of marine shells a very short distance above the local base of the Cretaceous and below the well-known concretionary greensands with Saurian bones. Some of the fossils are very much rolled, as though it had been an old shore-line, but unfortunately they are badly preserved. *Ostræa* is very plentiful, and there are many specimens of a shell I took to be *Conchothyra parasitica*, but which turns out to be an apparently undescribed form of *Pugnellus*. The Waipara Gorge affords the most important continuous section in New Zealand of the Cretaceous and Tertiary beds.

Waimakariri Gorge.

This locality is about 40 miles west-north-west of Christchurch. The station is Kowai Bush, and a section of Cretaceous beds resting unconformably on semi-metamorphic greywackes and argillites of uncertain age is exposed in a deep gorge of the river. The fossiliferous band is not far above the junction, and consists of some 3 feet of glauconitic greensand crowded with *Conchothyra parasitica*, the only other fossil being an occasional badly preserved valve of *Trigonia Hanetiana*.

Wangaloa.

This locality is on the coast about 35 miles south-west of Dunedin, and forms part of the Kaitangata Coalfield. Fossils occur in a calcareous sandstone with some glauconite. Professor Marshall has

a bed of blackish-grey calcareous shale which shows no trace of cone-in-cone structure. I noticed in some places that where the concretions had been affected by subsequent pressure in the bed the action of the pressure tended to obliterate again the cone-in-cone structure in the outer layer of the nodules.

recently shown that the fauna here is distinct from the usual Cretaceous such as occurs at Selwyn Rapids, and that a shell which occurs here and was formerly supposed to be *Conchothyra parasitica* is really a new species of *Pugnellus*. Neither Ammonites nor Belemnites have yet been found in this bed. Marshall has recently published[1] a provisional list of fifty-two species of Mollusca from this locality which seems to include a considerable number of Tertiary Oamaru forms and even some recent species. He is at present investigating this fauna more closely. I made a fairly large collection one day at this locality, but I await Professor Marshall's work before reporting on them.

PALÆONTOLOGY.

TRIGONIA cf. HANETIANA, d'Orb. (Pl. XXI, Fig. 5.)

Voyage dans l'Amérique Paléontologie, 1842, p. 127, pl. xii, figs. 14–16.
Philippi, Die quatären und tert. Versteinerungen Chiles, 1887, p. 199, pl. xlii, figs. 1–3.
Steinmann, "Die Gastropoden u. Bivalven der Quiriquina-Schichten": N.J. für Min., Beilage Bd. x, p. 101, pl. vii, figs. 8, 9, 1895.
Hector, Catalogue Ind. and Col. Exhibition, 1886, p. 64, fig. 5, *Trigonia sulcata*.

The only other shell I saw in the *Conchothyra* bed in the Waimakariri Gorge was a *Trigonia*, which occurred as single valves in a friable and fragmentary condition. I collected the pieces of one and succeeded in joining them together. It is undoubtedly the shell that Hector illustrates without any description under the name *Trigonia sulcata*. The curious double sculpture on the anterior part of the shell makes this quite certain. Steinmann notices Hector's figure, and compares it with *T. Hanetiana* from Quiriquina, in Chili, and remarks "that of all known forms of *Trigonia* the only one which compares with *T. Hanetiana* is one illustrated by Hector under the name *T. sulcata* from the lower (*sic*) Cretaceous of New Zealand. Both forms are obviously very closely related and represent a genuine Pacific form, for which it would be best to institute a special group". He goes on to say that it does not fall well into any of Lycett's *Trigonia* groups.

My specimen is a right valve, and unfortunately lacks the hinder part, but enough remains to give a fair description of it. The beak is rather anterior and the shell considerably elongated behind. The ridge which passes from the beak to the hinder part is bluntly angular, the sides making nearly a right angle with one another, and in front there is a wide shallow groove almost devoid of sculpture. Between this and the rounded anterior margin the surface is ornamented with broad and shallow concentric growth grooves which are crossed obliquely by a series of about six broad and low ridges, which are arranged parallel to the main posterior ridge and gradually diverge and increase in size as they pass from the upper anterior part of the shell backwards to the lower margin. Where they are strongest they tend to obliterate the concentric grooves of growth. The teeth cannot be seen. Height 50 mm.

[1] "Relations between Cretaceous and Tertiary Rocks": Trans. N.Z. Inst., vol. xlviii (new issue), p. 114, 1915.

I am inclined to think the New Zealand shell is identical with *T. Hanetiana*, but owing to the poor condition of the only specimen I collected I cannot be quite certain.

Wilckens[1] describes another form, *T. ecplecta*, from the Upper Cretaceous of Baguales in South Patagonia, which, though larger, is certainly related to *T. Hanetiana*, but on which the cross ribs are confined to the upper anterior portion of the shell, and the concentric furrows are much stronger.

T. Hanetiana belongs to the commonest fossils of the Chilian Upper Cretaceous, and together with *Cardium acuticostatum*, d'Orb., is regarded as a leading fossil of the Quiriquina Beds.

I found no Trigonias at Selwyn Rapids, but I believe they occur there.

Dentalium sp. (Pl. XXI, Fig. 10. × 2 nat. size.)

Shell slightly curved, increasing slowly in size, rather thin, and almost circular in section. The surface is rather rough, and the growth-lines are well marked. A specimen I collected resembles *D. Chilensis*, d'Orb., which is common at Quiriquina, but is without the longitudinal striæ that occur on the thin end of that species. It is comparable also with *D. Cazadorianum*, Wilckens, from South Patagonia.

Locality.—Selwyn Rapids. Dentaliums of fairly large size are common, generally as casts in some parts of the rock.

Turritella sp. (Pl. XIX, Fig. 11. × 2½ nat. size.)

Shell small, consisting of seven whorls, which increase very gradually. The test is rather thin, the sutures are shallow, and each whorl is decorated with seven or eight very faint spiral raised ridges.

Locality.—Selwyn Rapids.

Chrysostoma Selwynensis, sp. nov. (Pl. XXI, Figs. 4*a*, *b*.)

Shell very small, thick, and globose, consisting of five whorls. Surface smooth and rounded, sutures shallow. There is a faint umbilicus which is more or less covered by a reflected callus extension of the inner lip. The outer lip, though broken, seems to have been sharp. Height 5 mm. I can find no described form in the Indo-Pacific Cretaceous resembling this small and insignificant-looking shell, and so am constrained to give it a new specific name. The only living representative of the genus to which it certainly seems to belong is a beautiful shell, *C. paradoxum*, Born, found on the shores of New Caledonia.

Locality.—Selwyn Rapids, one specimen.

Natica (Euspira) variabilis, Moore. (Pl. XIX, Figs. 8–10.)

Charles Moore, Quart. Journ. Geol. Soc., vol. xxvi, p. 256, pl. x, fig. 15, 1870. Jack & Etheridge, Geol. and Pal. Queensland, 1892, p. 485, pl. xxxi, figs. 2, 3. R. B. Newton, Proc. Malac. Soc., vol. xi, pt. iv, p. 232, pl. vi, figs. 21–3, 1915.

The New Zealand form of this Australian fossil is rather variable. One specimen (Fig. 8) has four volutions, is broader than it is high,

[1] Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 37, pl. vii, figs. 2, 3, 1907.

and is rather depressed. The body-whorl is large and globose and increases rapidly in size. The surface is rather eroded and bears closely spaced rather foliaceous growth-lines. The suture is somewhat deep and the whorls are not flattened below it, and there are no parallel striæ on the basal part of the body-whorl. It measures 16 mm. high and resembles a specimen figured by Jack & Etheridge, pl. xxxi, fig. 2. Another specimen (Fig. 9) differs in having a more elevated spire, the suture is not insunken and the whorls are flattened just below it, and the body-whorl is relatively smaller and less swollen. About six fine rounded concentric ridges occupy the base of the body-whorl near the umbilicus, and the growth-lines are much less strongly marked than in the first variety. It is smaller in size and resembles the specimen figured by Jack & Etheridge, pl. xxxi, fig. 3. Another smaller specimen (Fig. 10, × 1½ nat. size) resembles the last, but the concentric ridges occupy the whole of the body-whorl.

This shell agrees in every way with the Australian form, and is the only Australian Cretaceous fossil I found in the New Zealand rocks. Mr. R. B. Newton has recently discussed the generic affinities of this shell in a paper quoted above dealing with the fossils of the opal deposits of the interior of New South Wales.

It occurs in the Rolling Downs Formation of the Lower Cretaceous, and also in the Desert Sandstone, Upper Cretaceous, in Australia. I have a specimen from the opal deposits of Whitecliffs, New South Wales.

Locality.—Selwyn Rapids, where it is not scarce. I did not find it in any other locality, and this is the first record of the occurrence of this typically Australian form in New Zealand and forms the sole connecting link among my specimens with the Australian Cretaceous.

NERITOPSIS (?) SPEIGHTI, sp. nov. (Pl. XIX, Figs. 12–15.[1])

The shell consists of four or five whorls, and in young specimens is thin and oval in shape. In the adult state it is more rounded owing to flattening of the spire and rapid enlargement of the body-whorl. The spire in immature specimens is pointed and rather elevated, but in the adult specimen it is flattened through erosion or wear. In the largest example there is a faint umbilicus, the peristome is entire, and the inner lip is somewhat detached from the body-whorl. The lip is thickened for some distance back from the margin, but ends in a sharp rim. The body-whorl is decorated with about fifteen raised concentric parallel rounded ridges, alternating with furrows of about the same width and depth. On the earlier whorls the furrows are less strongly marked. The growth-lines are rather faint, but are interrupted here and there on the body-whorl by a strong furrow.

In the absence of knowledge of the operculum or of the animal it is impossible to fix with certainty the genus of this shell, as many genera quite unallied to one another develop parallel concentric furrows, such as *Cinulia*, *Dolium*, *Pyrula*, *Fossarus*, and many others.

The moderate thickness of the shell and increasing thickness of the adult lip and sharpness of the aperture point to *Neritopsis*

[1] Fig. 15 is × 2 nat. size.

as being the most likely genus. It also resembles *Vanikoro*, but the shell seems too thick and the inner lip too strongly developed. The partial detachment of the inner lip from the body-whorl and the complete peristome suggests the genus *Fossarus*, which together with *Vanikoro* has a horny operculum, whereas that of *Neritopsis* is thick and stony. There is no trace of columellar folds nor of a reflected lip which might connect it with *Cinulia* or *Eriptycha*.

The erosion or battering which the spire has suffered in the adult specimen points to its being some shore-loving form, but whether of the Littorinidæ or Neritopsidæ is uncertain, but I think the genus *Neritopsis* is the more likely one.

Locality.—Selwyn Rapids.

The only species I can trace which at all resembles the present form is *Vanikoro Kiliani*, Wilckens,[1] which occurs at Snow Hill and Seymour Island in Antarctica. But this is a very small shell and consists only of three to four whorls and has fourteen spiral ribs, the spaces between which are not always equal and the ribs are preserved only on the last whorl. I take the opportunity of naming this shell after my friend Dr. R. Speight, director of the Christchurch Museum, who has published many papers on New Zealand Geology, and who assisted me to collect several of the Cretaceous fossils.

CONCHOTHYRA PARASITICA, McCoy. (Pl. XX, Figs. 4, 5.)

Hector, Cat. Ind. and Col. Exhib., 1886, p. 58, fig. 4.
Park, Geol. New Zealand, 1910, p. 90, pl. v (after Hutton).

This extraordinary Gasteropod is the most abnormal of the curious group of the Pugnellids. The smooth callosity of the inner lip is more exaggerated than in any other species of the group, and in some specimens it extends beyond the apex and sometimes almost buries the spire. The thickened claw-like outer lip is very large and heavy, and the growth-lines and ridges on the body-whorl are very exaggerated.

If the genus *Conchothyra* is to be retained—and in view of its frequent mention in New Zealand geological literature and the great specialization of the shell in question I think it should be—it may be re-defined as follows:—

Shell as in *Pugnellus*, but the early whorls are smooth and devoid of nodes or ribs. Spire short and in fully grown specimens almost buried by the labial callosity, and often scarcely visible owing to erosion. The lines and ridges of growth are coarse and prominent on the last whorl. The anterior channel of the mouth is deep and narrow, the posterior channel is shallower and more or less semi-circular in shape. The outer lip is much thickened and often greatly prolonged.

I think this curious mollusc may have been of a sluggish character and have lain partly buried in sand. Both the great weight of the shell and its frequent erosion suggest this mode of life. That part of the body-whorl on the back below the spire is generally very thin,

[1] "Die Anneliden, Bivalven, u. Gasteropoden der antarktischen Kreide, 1910": Wissensch. Ergebnisse der Schwed. Südpolar Exped., p. 77, pl. iii, figs. 28*a*, *b*.

apparently by absorption or erosion. In one of my specimens there is a small *Anomia* attached to the surface near the inner lip which suggests that the shell may have lain mouth upwards in the sand.

Locality.—In the Upper Waimakariri Gorge there is a bed about 3 feet thick not far above the local base of the Cretaceous almost made up of thousands of these shells, some perfect and others broken. They show considerable variation in the degree of growth of the shelly callosity and the extension of the lip. The only other fossil that I found associated with them in this locality were a few valves of *Trigonia Hanetiana*, d'Orb. At Selwyn Rapids the shell is less plentiful, and is better preserved in the harder parts of the rock, but is in all respects similar to the specimens at Waimakariri.

It seems, as one might expect in so specialized a shell, to have a restricted vertical range, and may be regarded as a characteristic fossil of the Upper Senonian.

This form is apparently quite absent from the higher Wangaloa Beds, where it is replaced by a beautiful shell recently described by Professor Marshall as *Pugnellus australis*.

PUGNELLUS MARSHALLI, sp. nov. (Pl. XIX, Figs. 1–4.)

The shell consists of six whorls, the last one large and inflated. Above the middle of each whorl there is a row of blunt nodes, and below these on the last whorl a row of smaller and less prominent nodes which in some specimens coalesce into a raised ridge. The sutures are shallow. The outer layer of the shell bears very fine concentric raised lines.

The lip is not developed to the exaggerated extent it is in some forms of *Pugnellus*. The outer lip is extended and swollen, and ends in a rounded claw-like protuberance which is very easily broken off. Anteriorly there is a channel, but the shell is not drawn out. Posteriorly there is a wide semicircular channel formed by the swollen lip of the shell. The callosity of the inner lip reaches in most specimens to the top of the third whorl from the mouth, and in one or two examples it extends above this nearly to the apex. It is a shell of moderate size, the height being about 26 mm.

This shell was formerly erroneously supposed to be a *Struthiolaria* or *Pelicaria*, and a specimen was recently identified as such by Mr. Suter, and Prof. Marshall[1] remarks that it is the first occurrence of the essentially Tertiary form *Struthiolaria* in Cretaceous rocks.

I obtained, however, nine or ten perfect examples with entire lips and can definitely say that it is a true *Pugnellus*. It often happens that the specimen is immature or the lip is missing when the sculpture on the earlier whorls of the shell certainly recalls that on the recent *Pelicaria*. However, in no *Struthiolaria* that I have seen does the labial callosity extend to beyond the lower half of the penultimate whorl. The same remark applies to *Pelicaria*, which has in addition a thin smooth shelly deposit covering the back of the last and penultimate whorl. Neither *Struthiolaria* nor *Pelicaria* has the thickened and swollen outer lip characteristic of *Pugnellus* which is so conspicuous in the present shell.

[1] Trans. N.Z. Inst., vol. xlviii, p. 118, 1915.

Locality.—Selwyn Rapids, where it is rather common.

I name this species after Professor P. Marshall, who has done so much in elucidating the geology of New Zealand and in calling attention to the problems of the Cretaceo-Tertiary question in the South Pacific region.

PUGNELLUS WAIPARENSIS, sp. nov. (Pl. XX, Figs. 1*a*, *b*.)

The spire is moderately elevated and the shell consists of six whorls. The shell is almost completely overgrown up to the summit of the spire with a platy extension of the lip, and only when this is broken away is the spire visible and the nodes and ornamentation of the whorls seen. The earlier whorls are decorated with folds which develop into elevated and rather sharp nodes. These are placed in a diagonal position on the shell rather above the suture on the penultimate whorl, and are faintly visible on the body-whorl where they occur above the median line. Below these nodes on the last whorl there is a blunt faintly raised ridge.

A series of fine, rather wavy, spiral, raised lines occur on the penultimate whorl and are faintly seen on the body-whorl below the ridge. They run somewhat irregularly and are not exactly parallel to one another, but approach and recede again, a peculiarity already noticed by Wilckens in the case of *Pugnellus Hauthali*,[1] which he describes from South Patagonia. The anterior channel of the lip is not produced, and the outer margin of the lip is not swollen to an unusual extent for a *Pugnellus*.

This shell approaches *P. Hauthali* in having the spire completely covered with a leafy shell growth and in the diagonal arrangement of the elongated and sharp nodes and in the curious non-parallel arrangement of the spiral lines. It differs in the spire being more elevated and the anterior channel not being elongated and the outer lip being less swollen and extended.

Locality.—Waipara Gorge, in beds with *Ostrea* near the local base of the Cretaceous and well below the Saurian concretionary beds. It occurs plentifully, but often rolled and poorly preserved. It has hitherto been mistaken for *Conchothyra parasitica*, and I thought it was a small variety of that shell, but I find on developing my specimens that it is a *Pugnellus* that I cannot identify with any described form. I found no *Conchothyra* in the bed in which it occurs.

PUGNELLUS AUSTRALIS, Marshall; variety. (Pl. XX, Figs. 2*a*, *b*.)

Trans. N.Z. Inst., vol. xlviii, p. 120, pl. xi, figs. 1-3, 1915.

Professor Marshall has recently described a highly decorated shell which occurs rather commonly at Wangaloa. When I visited that locality in his company I collected several examples of the shell, two of which, when developed, prove to be excellently preserved. One of them closely resembles his type-specimen, Fig. 2, but the other differs in having a much more exaggerated development of the lip than any of his three figured examples and is apparently an aged specimen.

[1] Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 18, pl. iv, figs. 2*a*, *b*, 1907.

The spire is almost concealed, and the callosity extends far beyond it and is produced into a finger-like process which is bent away from the spire. The outer lip is much thickened and produced upwards, and the interior portion of the lip is provided with a second channel through excessive growth of the callous margin. I think this variety, Figs. 2*a*, *b*, is sufficiently distinct to warrant its illustration for comparison with the more normal type, Figs. 3*a*, *b*, and to complete the illustration of the Pugnellid shells which have so far been found in New Zealand.

Locality.—Wangaloa. Maestrichtian (?).

Alaria Suteri, sp. nov. (Pl. XIX, Fig. 5. × 1½ nat. size.)

The shell consists of eight whorls which increase gradually in size. The lip of the last whorl is moderately expanded to a simple curved outline and is not digitate. It ends anteriorly in a blunt termination beneath which there is a shallow channel. The posterior margin of the lip does not seem to be channelled, and the labial expansion extends about half-way up the penultimate whorl. The whorls are decorated with rather widely spaced curved ribs, recalling those of *Scalaria* or of the recent *Aporrhais occidentalis*, Beck. On the last whorl these ribs reach from the suture to rather beyond the middle line, where they meet a blunt ridge. The whole surface of the outer layer of the shell is covered with very fine parallel raised concentric lines which continue over the ribs. Length about 35 mm.

The earlier whorls of this shell strongly recall those of a *Scalaria*, and resemble a fragment of six whorls from Quiriquina that Wilckens illustrates[1] under the name *S. araucana*, Phil., only that the varices are rather closer together than they are on the New Zealand shell.

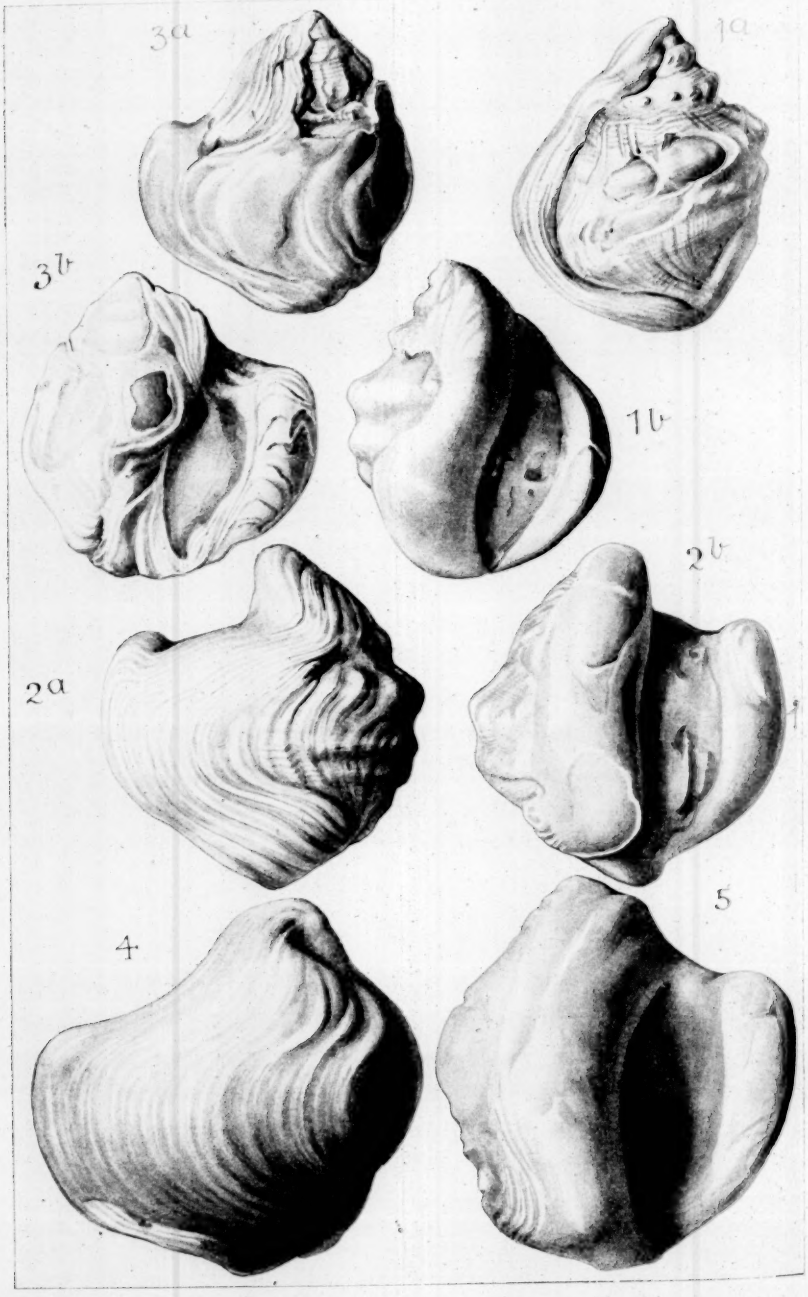
Locality.—Selwyn Rapids. I name this species, which I cannot identify with any described form, after Mr. H. Suter, of Christchurch, the leading authority on the recent Mollusca of New Zealand.

Aporrhais gregaria, Wilckens. (Pl. XIX, Figs. 6, 7.)

Berichte der Naturf. Gesell. z. Freiburg, Bd. xv, p. 16, pl. iii, figs. 10–13; pl. iv, fig. 1, 1907.

The shell consists of seven or eight whorls, the last one of which is swollen and expanded. The margin is channelled anteriorly and is not digitate, but extends to a rather sharp projection, which is produced backwards in a direction almost parallel with the spire. Between this projection and the body of the shell the lip has a broad shallow posterior channel. The shell is ornamented with a line of nodes which occur rather above the median line of the last whorl. Beneath them on the last whorl there is a series of much smaller and more numerous nodes that tend to coalesce into a raised ridge. The surface is decorated with a series of more or less continuous parallel raised ridges which are most apparent above the nodes on the penultimate whorl and on the lip. Growth-lines are rather prominent and irregular especially on the last whorl.

[1] N.J. für Min., Beil. Bd. xviii, pl. xviii, fig. 1, 1904.



G. M. Woodward, del. Bale & Sons, imp.

UPPER CRETACEOUS GASTEROPODA, NEW ZEALAND.

I am fortunately able to identify this form with certainty with the above shell, which Wilckens describes from Cazador, Sierra Contreras, and other places in South Patagonia between Lago Argentino and Last Hope Inlet. He illustrates several examples and says that the species is one that does not compare closely with any other *Aporrhais* known to him.

Locality.—Selwyn Rapids. I collected two specimens with spire and lip, one of them in fine condition which required to be laboriously chipped out and pieced together again. The spire in the better specimen (Fig. 6) is rather higher and more tapering than in the other. The shell that Hector[1] figures under the name *Rostellaria Waiparensis* is probably intended to represent this species.

EXPLANATION OF PLATES XIX AND XX.

All figures natural size unless otherwise indicated. All except *Pugnellus australis* are of Upper Senonian age.

PLATE XIX.

FIGS.

1–4. *Pugnellus Marshalli*, sp. nov. Selwyn Rapids.
5. *Alaria Suteri*, sp. nov. Selwyn Rapids. × 1½ nat. size.
6. *Aporrhais gregaria*, Wilckens. Selwyn Rapids.
7. Ditto, another specimen showing upward extension of the lip. Selwyn Rapids.
8–10. *Natica* (*Euspira*) *variabilis*, C. Moore. Selwyn Rapids. Fig. 10 is × 1½ nat. size.
11. *Turritella* sp. Selwyn Rapids. × 2½ nat. size.
12–15. *Neritopsis* (?) *Speighti*, sp. nov. Selwyn Rapids. Fig. 15 is × 2 nat. size.

PLATE XX.

1*a*, *b*. *Pugnellus Waiparensis*, sp. nov. Waipara Gorge.
2*a*, *b*. *Pugnellus australis*, Marshall, variety. Maestrichtian (?). Wangaloa.
3*a*, *b*. *Pugnellus australis*, Marshall, normal form. Wangaloa.
4. *Conchothyra parasitica*, McCoy. Waimakariri Gorge.
5. Ditto, same locality. Another specimen.

(*To be concluded in the August Number.*)

III.—Some Tertiary Dykes of the Clyde Area.

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Introduction.

THE very numerous Tertiary dykes of the Clyde islands (Arran, Bute, and the Cumbraes), and of the adjacent mainland and peninsulas, have been little studied either from the geological or petrographical point of view; but they are of great interest, not only in themselves, but as providing a link between the dykes of the better known areas of the North of England, and of Skye and Mull. The material is not yet gathered on which could be based a complete account of the series. The present paper is designed to present a full description of a hitherto unrecognized type of Tertiary dyke, typically exposed in the Great Cumbrae, and to indicate its relationships to other types already described from Mull and the North of England. Furthermore, a few other dykes from the Clyde area, all of basaltic composition, will be briefly described.

[1] Cat. Ind. and Col. Exhibition, 1886, p. 58, fig. 3.

The dykes of Arran have been the subject of geological inquiry since the beginning of the nineteenth century (Harker, 1903, Bibliography, pp. 181–90 [1]). Their extraordinary abundance has attracted much attention, but little is as yet known of their petrographical characters. Still more is this the case in regard to the Tertiary dykes of Bute, the Cumbraes, and the Ayrshire and Argyllshire mainland. Sir A. Geikie has gathered together all that was previously known of the geological and petrographical characters of the Tertiary dykes, and has supplemented it with the facts gained during his own numerous traverses of the Tertiary volcanic districts (1897, pp. 118–80). He distinguishes the great solitary dykes (e.g. the Cleveland dyke of the North of England) from the gregarious dykes, which are shorter, narrower, more basic, than the solitary dykes, and are closely crowded together in restricted areas. Petrographically he divides them into four groups—(1) normal basalts and dolerites; (2) andesites; (3) trachytes (Cowal); (4) acid dykes, felsite, quartz-porphyry, pitchstone, etc., which are arranged in the order of age. The first group, basalts and dolerites, include by far the greater number of the dykes, especially those of the gregarious type, whilst the great solitary dykes generally belong to the second group, the andesites.

The Geological Survey memoir on Cowal (1897, pp. 126–71) contains abundant geological information as to the Tertiary dykes of that part of the Argyllshire mainland bordering the Firth of Clyde. Sir J. J. H. Teall's petrographical descriptions of some of these dykes suggest relationships to the Cumbrae dykes described later in this paper.

The Tertiary igneous rocks of Arran, South Bute, and the Cumbraes are the subject of a chapter by Dr. A. Harker (1903, pp. 103–27) in the Geological Survey memoir on that area. In this chapter the Tertiary dykes are briefly treated under the headings dolerite and basalt, augite-andesite, pitchstone, and devitrified pitchstones. One or two Arran dykes with special characters have been previously described by me (Tyrrell, 1913, 1916); and Dr. W. R. Smellie (1916) has recently described some of the Tertiary dykes of Bute.

The Cumbrae Type of Tertiary Dyke (*Cumbraite*).

The Great Cumbrae is traversed by several large and finely exposed Tertiary dykes of a peculiar petrographical character and striking macroscopic appearance. They consist of a black glossy rock, with a tendency to vitreous lustre, in which are embedded numerous phenocrysts of white or yellow, fresh, plagioclase felspar, which proves to be near anorthite in composition. In the field they form prominent wall-like exposures trending to the N.N.W., upon the lowest raised beach which encircles the island. The Lion Rock, near Keppel Pier, is one of these dykes which has been broken in such a way that its profile suggests a couchant lion. It rises to a height of 15 feet, with a thickness of 16 feet, whilst a second dyke

[1] See list of references at end of paper.

adjacent to the Marine Biological Station at Millport attains a height of 30 feet above the raised beach, and averages 20 feet in width. The exposure from which the type-rock has been taken occurs on the raised beach at Eerie Port on the north-west side of the island. This dyke is 29 feet wide, has a N.N.W. trend, and a slight hade to the W.S.W. Its central part has locally a more vitreous lustre or pitchstone-like appearance than other parts. Petrographical examination shows that this appearance is not due to greater richness in glass, but to its slightly fresher character. All parts of the dyke show small cavities partly or wholly filled with bitumen. This dyke can be traced inland for about a mile, which is about as far as the Lion Rock and the Marine Biological Station, where dykes can also be traced. Other and smaller dykes of the same character occur around the shores of the island.

a *b*

FIG. 1*a*.—Cumbraite, N.N.W. dyke, Eerie Port, Great Cumbrae. × 20. Large phenocryst of anorthite; groundmass: laths of labradorite, enstatite, augite, in base of dark glass.

,, 1*b*.—Cumbraite (Eskdalemuir type), W.N.W. dyke, Waterhead Burn, Muirkirk, Ayrshire. × 20. Microphenocrysts of labradorite and magnetite; groundmass: felspar microlites, grains of augite and enstatite, in base of dark glass.

Under the microscope (Fig. 1*a*) these rocks show phenocrysts of plagioclase near anorthite, in a groundmass of laths of acid labradorite ($Ab_1\ An_1$), enstatite, augite, and abundant glass. The phenocrysts are extraordinarily fresh, with both Carlsbad and albite twinning usually well developed. They may reach a diameter of 1 cm. Twinning, cleavage, and refractive index methods agree in determining the composition of the felspar as between $Ab_{15}\ An_{85}$ and $Ab_{10}\ An_{90}$, i.e. anorthite near bytownite. The mineral, moreover, has a negative optical character which agrees with this determination. All the crystals have a narrow border of optically positive labradorite

(Ab_1 An_1). The contact between the two felspars is remarkably sharp, giving a well-marked "bright line" effect. The marginal labradorite has the same width whatever the size of the phenocryst, and has a very ragged, crenulated, or spiky margin against the glass of the groundmass, as though the glass had penetrated along the cleavage cracks. The anorthite phenocrysts carry numerous globulitic inclusions and "negative crystals" of dark glass extended parallel to 010. These are zonally arranged or confined to the centres of the crystals. The groundmass shows labradorite laths and pyroxene prisms embedded in a dark glass, the crystalline and glassy matter being about equal in bulk. The felspars form elongated laths, with bifid or trifid terminations, and a maximum extinction angle of 28 degrees, indicating acid labradorite (Ab_1 An_1). The chemical analysis shows that the orthoclase molecule must be present, but it does not appear in crystalline form, and must be incorporated in the glass.

The pyroxene includes both enstatite and augite, which are usually intergrown in characteristic fashion, with the augite always occurring on the margins. A common appearance is of three prisms in parallel position, two of augite on the margins, and a stout crystal of enstatite occupying the centre. Frequently, however, the enstatite occurs without the flanking augites, especially in the other Cumbrae dykes. It then carries minute specks of magnetite in a marginal zone. It is quite fresh, colourless, with straight extinction, positive sign, and has the heavily outlined cross-fracturing often seen in the orthorhombic pyroxenes. The augite is also colourless and has an extinction of 36 degrees.

The apparently dark-brown or black glass of the groundmass may be resolved under a high-power objective into a colourless or pale-yellow glass darkened by innumerable black globulites. It also carries numerous curved felspar microlites, and little strings of iron-ore granules which may represent original microlites of pyroxene. The apparently more glassy part of the Eerie Port dyke differs from the stonier part only in the greater freshness of its glass. The glass of the stony part always shows the beginnings of devitrification.

The other dykes of this type in the Great Cumbrae differ from the Eerie Port dyke only in minor details, such as the relative abundance of phenocrysts or the glassy base.

Mode.—An attempt was made to determine the quantitative relations of the minerals in the Eerie Port dyke by the Rosiwal method, but owing to the presence of glass, the fine grain, and the consequent uncertainty as to the exact boundaries of the minerals, the results must be regarded as only approximate. The anorthite phenocrysts were estimated from a number of hand-specimens. Table I shows the results of measurements for the "stony" (1) and "glassy" (2) parts of the Eerie Port dyke.

These figures show that this rock, if holocrystalline, would have been dofelsic. The glassy material contains little or no ferromagnesian constituents, as shown later. As regards texture, the rock is megaphyric (large phenocrysts), hyalocrystalline (glass and crystals

developed in approximately equal quantity), and perpatic (groundmass overwhelmingly predominant over phenocrysts).[1]

TABLE I.

	1.	2.
Anorthite ($Ab_1 An_9$) . .	7	10
Labradorite ($Ab_1 An_1$) . .	31	26
Pyroxenes	20	22
Glass	42	42
Specific gravity .	2·706	2·680

The composition of the glass may be calculated from the chemical analysis (Table II, 1) by deducting the mineral constituents in the proportions shown in Table I. After deducting 7 per cent of anorthite ($Ab_1 An_9$) and 31 per cent of labradorite ($Ab_1 An_1$), and assigning all the TiO_2 and Fe_2O_3 to ilmenite and magnetite respectively, the rest of the ferrous iron and lime with magnesia and the proper quota of silica form just 20 per cent of pyroxene, thus affording good evidence of the accuracy of both mineral and chemical analyses. All the mineral constituents have now been deducted; and as the ilmenite and magnetite may be held to represent the dark globulites in the glass, the remaining potash, soda, alumina, and silica must be present in the colourless glass, which must have the approximate composition SiO_2, 80·4; Al_2O_3, 9·9; Na_2O, 3·7; K_2O, 6·0. There is a small defect of Al_2O_3 as compared with the amount required to make orthoclase and albite molecules of all the potash and soda. It is possible, therefore, that there is a slight defect of Al_2O_3 in the analysis of the rock. From these results it may be concluded with fair probability that, apart from the dark globulites, there is no iron, magnesia, or lime in the glass, and that it consists entirely of orthoclase, albite, and free silica molecules.

Chemical Composition.

The chemical composition of the Cumbrae dyke and of the similar dyke of Eskdalemuir, is set out in Table II, 1, 2. Compared with average andesite (II, 5) and average hypersthene-andesite (II, 6), they have the same amount of silica and alkalies, less alumina, but higher ferrous iron and lime. The Cumbrae types are therefore slightly more femic than the average andesites, but have a somewhat more sodic plagioclase felspar, as is well shown by the norms (Table III, 1, 2, 5, 6).

The comparison between the two cumbraites is hindered by the non-determination of TiO_2 in the Eskdale rock; but the smaller Al_2O_3 and lime, and the higher ferrous iron and magnesia, of the latter, cause a reversal of the relative proportions of diopside and hypersthene in the norms of the two rocks (Table III, 1, 2). The Eskdale rock is slightly more femic and less quartzose than the Cumbrae rock, as is shown by the dashes following the symbols for class and order in the former.

[1] Iddings, *Igneous Rocks*, vol. i, pp. 187, 199, 1909.

TABLE II.

	1	2	3	4	5	6
SiO_2	60·46	58·57	61·69	64·13	59·59	59·86
TiO_2	·68	n.d.	1·00	1·19	·77	·66
Al_2O_3	14·85	14·37	14·43	13·15	17·31	16·93
Fe_2O_3	1·14	1·64	1·23	1·08	3·33	2·86
FeO	5·82	6·94	5·86	6·31	3·13	3·56
MnO	·10	trace	·30	·27	·18	·22
MgO	1·46	4·65	2·81	1·08	2·75	3·25
CaO	8·19	7·39	4·97	3·62	5·80	6·36
Na_2O	3·27	3·01	3·20	3·64	3·58	3·35
K_2O	2·20	1·42	1·72	2·32	2·04	1·62
H_2O above 105° C.	1·42	2·02	2·36	2·71	1·26	1·08
H_2O at 105° C.	·63		·25	·36		
P_2O_5	·05	—	·24	·31	·26	·21
BaO	—	—	·04	·09	—	·06
Cl	—	—	·02	—	—	—
	100·27	100·11	100·12	100·26	100·00	100·02

1. Cumbraite, Tertiary N.W. dyke (interior glassy facies), II, 4. 3. 4. (*tonalose*), Eerie Port, Great Cumbrae, Firth of Clyde. Anal. by Chetai Yu, B.Sc.; alkalies, TiO_2 and P_2O_5, by A. Scott, M.A., D.Sc.
2. "Pitchstone" (Cumbraite, Eskdale type), N.N.W. dyke with "sheath-and core" structure, II′, 4′. 3. 4. (*tonalose*), Eskdale, Dumfriesshire. Quoted from Sir A. Geikie, 1880, p. 253.
3. Leidleite (glassy part of sill showing "sheath-and-core" structure), II, 4. 3. 4. (*tonalose*), 2 miles S.S.W. of Pennyghael, Mull. Anal. E. G. Radley, Summ. Prog. Geol. Surv. for 1912 (1913), p. 69.
4. Inninmorite (inclined sheet, "contains small phenocrysts of basic plagioclase, and has acicular augite in the glassy base"), 'II, 4. 2 (3). 4. (*tonalose-dacose*), 1 mile S.S.W. of Pennyghael, Mull. Anal. E. G. Radley, Summ. Prog. Geol. Surv. for 1912 (1913), p. '69. For other analyses of leidleite and inninmorite see E. M. Anderson and E. G. Radley (1916, p. 212).
5. Average Andesite (Daly), 'II, 4. 3. 4. (*tonalose*). R. A. Daly, *Igneous Rocks and their Origin*, 1914, p. 26.
6. Average hypersthene-andesite, II, 4. 3′. 4. (*tonalose*). Calculated from 71 analyses of rocks described as hypersthene-andesite, hypersthene-augite-andesite, bronzite- and enstatite-porphyrite, enstatite-diabase-porphyry, and bronzite-tholeiite; taken from Iddings, *Igneous Rocks*, vol. ii, 1913; Iddings & Morley, paper on "Japanese Volcanic Rocks", Proc. Nat. Acad. Sci., Washington, vol. ii, 1916; Rosenbusch, *Gesteinslehre*, 3rd ed., 1910; Washington, Prof. Paper 14, U.S. Geol. Surv., 1903, etc.

Comparing the Cumbrae types with the related leidleite and inninmorite of Mull, it may be noted first that the latter are richer in combined water, and therefore in glass, than the Cumbrae types. Leidleite differs otherwise in containing a smaller percentage of lime, due probably to the absence of anorthite. This results in an almost exact reversal of the proportions of diopside and hypersthene in the norms of the two rocks (Table III, 1, 3), but otherwise the

analyses and norms are very similar and give identical symbols in the American Quantitative Classification. The analysis of inninmorite shows much less lime and more silica, causing its norm to have a more quartzose and alkalic character than that of the Cumbrae type. This is reflected in the symbols for class and rang; and inninmorite falls into the subrang *dacose*, but close to the border between *dacose* and the neighbouring subrang *tonalose*, into which all the other analyses fall.

TABLE III.

	1	2	3	4	5	6
Quartz . .	14·04	11·28	19·14	22·32	15·48	15·54
Orthoclase . .	12·79	8·34	10·01	13·34	11·68	9·45
Albite . . .	27·77	25·15	27·25	30·92	29·87	28·30
Anorthite . .	19·46	21·41	19·74	12·51	25·58	26·41
Diopside . .	17·79	12·71	3·00	3·13	1·33	3·59
Hypersthene . .	3·14	16·52	13·96	10·19	8·25	9·80
Magnetite . .	1·62	2·32	1·86	1·62	4·87	4·18
Ilmenite . .	1·37	—	1·98	2·28	1·52	1·37
Apatite . .	—	—	·51	·67	·67	·34
Class	II.	II′.	II.	'II.	'II.	II.
Order	4.	4′.	4.	4.	4.	4.
Rang	3.	3.	3.	2 (3).	3.	3′.
Subrang	4. Tonalose	4. Tonalose	4. Tonalose	4. Tonalose-dacose	4. Tonalose	4. Tonalose

Interesting points arise from the consideration of the analyses of average andesite and average hypersthene-andesite. Comparing the two, average hypersthene-andesite has slightly more ferrous iron, magnesia, and lime, but less alkalies than the average andesite. Hence, the average hypersthene-andesite is slightly more femic and more calcic than average andesite, as is well shown by the norms and the magmatic symbols (Table III, 5, 6). Furthermore, both averages show about 15 per cent of normative quartz, and fall into the subrang *tonalose* (II, 4, 3, 4). Rocks with analyses like these should be regarded as dacites according to the classification adopted by Iddings.[1] They would belong to varieties of his *shastaite* (andesine-dacite),[2] transitional to *bandaite* (labradorite-dacite), devoid of modal quartz. Most of the analyses in this group fall into the subrang *tonalose*. The rocks called "andesite" by petrographers contain then, on an average, 15 per cent of normative quartz, which, however, rarely appears in the mode, and must exist occult in a fine-textured or glassy base. The term dacite should be restricted to andesitic rocks so rich in excess silica that it appears as quartz in the mode. The average dacite of Daly[3] has 25 per cent of normative

[1] *Igneous Rocks*, vol. ii, p. 106, 1913.
[2] Ibid., p. 111.
[3] *Igneous Rocks and their Origin*, 1914, p. 25.

quartz and falls into the subrang *lassenose* (I′, 4 (2). 3. 4, *yellowstonose-lassenose*). Furthermore, if the average hypersthene-andesite, based on seventy-one analyses, be compared with the average hypersthene-andesite computed by Daly on twenty analyses, it will be found that the differences are quite insignificant. This testifies to the distinctness and solidarity of this petrographic type, as distinguished by many petrographers on the basis of mineral composition. There can be little doubt but that a similar result would be arrived at for many other rock-types.

Relationships and Nomenclature of the Cumbrae Type.

It is very difficult to place this rock under the existing system of nomenclature. Similar rocks from the North of England and elsewhere have been called "augite-andesite", "basaltic andesite", "andesitic basalt", "andesitic dolerite", "tholeiite", "basalt", etc., a list which sufficiently indicates the petrographers' perplexity. The rock can be regarded neither as a true andesite nor a true basalt. In chemical composition it approaches the andesites; but if the term andesite be limited (as it should be if used specifically) to volcanic rocks with predominant andesine felspar, the Cumbrae rock clearly does not fall within this group. Its mineralogical expression, on the other hand, approaches that of a basalt; yet it cannot be placed thereunder because its chemical composition, with 60 per cent silica, is entirely unlike that of basalts. A similar difficulty of nomenclature has been experienced with the related dykes of Mull, and the Survey petrographers have solved the problem by giving the rocks new locality names, such as leidleite and inninmorite. The root of the difficulty is, of course, the abundant glass in the rock, which, as has been shown, must contain the excess silica and alkalies above that necessary to form the visible felspars. The probable mineral composition had the rock been holocrystalline is given approximately by the norm. There would have been about 47 per cent of a felspar near $Ab_3 An_2$ (andesine), about 21 per cent pyroxenes, 12 per cent orthoclase, and 14 per cent quartz, i.e. the rock would have been a pyroxene-dacite; or, if the quartz had remained occult, as it appears to do in most andesites, a pyroxene-andesite.

Terms such as dolerite, basalt, andesite, dacite, and the like, have become far too comprehensive for a more discriminative petrography than frequently employed. If they are to be retained as more than mere field names, or comprehensive "omnibus" names, they should be frankly used as group or generic terms, comprising numerous sub-groups and species which should be given new names. Lacroix has recently begun the discrimination and renaming of ultrabasic forms of basalt and nepheline-basalt,[1] whilst Iddings has attempted to distinguish the numerous varieties of dacite, andesite, and basalt, according to their predominant felspar.[2]

If, however, nomenclature is based on mineral composition, there will always be a terminological difficulty with glassy rocks, for the greater the amount of glass the more abnormal will be the constitution

[1] A. Lacroix, *Comptes Rendus*, vol. clxiii, pp. 177-83, 213-19, 253-8, 1916.
[2] J. P. Iddings, *Igneous Rocks*, vol. ii, pp. 106, 191, 1913.

of the crystalline residuum as compared with the possible holocrystalline development. Glassy rocks are probably best named in such a way as to connect them with their nearest holocrystalline equivalents, and consequently, for accurate naming, the chemical composition will have to be determined in many cases. In general, however, petrographers will only find this necessary when the rock is of an abundant and widespread type not directly associated with its holocrystalline equivalent, as is the case, for example, with the rocks under discussion and the pitchstones of Arran.

The use of the dominant mineral constituents and texture as qualifying terms, and of the prefix *hyalo-*, in naming glassy rocks, results in some unwieldy designations, which may be illustrated as follows:—

Cumbraite = Anorthite-enstatite-augite-hyaloandesite.
Inninmorite = Anorthite-(uniaxial) augite-hyaloandesite.
Leidleite = Subvariolitic-augite-hyaloandesite.

In such cases the short locality-names, such as those given above, are much the more convenient for use when the rocks of a single petrographic province are being described, and for the Cumbrae rock I therefore propose the term *cumbraite*, which is defined according to the mineralogical and chemical composition given above. A new name should only be given to a glassy rock when it is an abundant, widespread, and homogeneous type, different either mineralogically or chemically from previously described glassy rocks, not when it is a mere hyaline facies of an associated holocrystalline rock. Whether these terms should obtain a circulation outside the discussion of the British Tertiary petrographic province is a question beyond the scope of this paper. My own opinion is that they should not, unless future work should show that they are widespread types in other petrographical periods and provinces.

Other Occurrences of Cumbraite.

Two dykes closely resembling the typical cumbraite occur on the Ayrshire mainland. One forms a N.W. dyke, 5 miles long, cutting across the River Ayr and its tributary the Coyle Water, near Sundrum House, about 6 miles east of Ayr. This rock is somewhat decomposed, but the anorthite phenocrysts remain fresh, and the enstatite is clearly recognizable by its pseudomorphs. The other occurrence is in the Burnock Water near Ochiltree, and appears to be quite a short dyke. In thin section this rock is seen to contain rather less glass than the typical cumbraite, and is richer in felspar and pyroxenes, especially the latter, thus providing a transition to the true tholeiites. The enstatite is pseudomorphed by a green fibrous mineral.

In the Cowal peninsula of Argyllshire a perfectly typical cumbraite occurs at Toward (Clough, 1897, pp. 131–2, 136).[1] This dyke is said to have a glossy band in the interior, running parallel with the length of the dyke, a feature connecting it with the Eerie Port dyke of the Cumbrae. A slightly different type which may, however,

[1] I am obliged to the Geological Survey for the loan of the Cowal slides on which these remarks are based, and also for the Eskdalemuir slides.

still be referred to cumbraite, occurs near Cruach Chuilceachan, in Cowal. This rock has been described by Sir J. J. H. Teall (in Clough, 1897, p. 155). It shows reticulations and bandings of varieties differing in texture and amount of glass. It carries glomero-porphyritic groups of basic felspar and hypersthene in a richly glassy groundmass containing microlitic felspar and augite.

The great Eskdalemuir (Dumfriesshire) dyke described by Sir A. Geikie (1880, pp. 219–55; 1897, vol. ii, pp. 133 et seqq.) forms a distinct variety of cumbraite distinguished texturally from the Cumbrae rocks. In the latter both the felspars and pyroxenes of the groundmass are slender and elongated, and may show a tendency to subvariolitic groupings, as also in the leidleite and inninmorite of Mull. In the Eskdalemuir type (Fig. 1*b*) the felspars are much broader, giving almost square or rhomboidal outlines, and the augite tends to form small clusters of minute, granular, equidimensional crystals. The enstatite stands out, however, as somewhat larger prismatic crystals. The abundant glass is yellow and comparatively free from microlites. Further differences are the comparative paucity of the large phenocrysts of anorthite, and the presence of sharply crystallized and uniformly distributed grains of magnetite in the Eskdalemuir type. Sir A. Geikie has noted the occurrence of curious enclosures of almost or quite holocrystalline material consisting mainly of granular augite and felspar laths. The "sheath-and-core" structure, of which this rock presents the type, must also be mentioned, as it appears, more or less perfectly, in many of the rocks treated in this paper. This rock may be distinguished as the Eskdalemuir type of cumbraite. The contrast between the textures of the two types is shown by Figs. 1*a* and 1*b* (see also Teall, 1888, pl. xiv, fig. 1).

Rocks probably belonging to the Eskdalemuir type occur in the four great W.N.W. dykes which traverse the Muirkirk district of Ayrshire, the most southerly of which is the continuation of the Eskdalemuir dyke. Enstatite, however, is not so abundant in these dykes as in those described above, and is always represented by green pseudomorphs. Furthermore, the anorthite phenocrysts are both small and sparse, and may be locally absent. The yellow glass of the groundmass provides abundant quartz on its devitrification.

At least two dykes in the Cowal area belong to the Eskdalemuir type and show the "sheath-and-core" structure, as described by Clough (1897, pp. 135, 142). The Cruach Mhor dyke carries a considerable amount of enstatite in small prisms. The dyke near Brackleymore School shows enstatite in central intergrowth with augite, but frequently decomposed to a fibrous green mineral of straight extinction. A dyke from the burn half a mile west of Loch na Leirg, Whiting Bay, Arran, possesses affinities with this type.

Typical cumbraites have not yet been found in Arran, but rocks which may represent an almost holocrystalline development of the cumbraite magma occur as north-west dykes penetrating the great sill of teschenite or crinanite at Dippin (Tyrrell, 1916, pp. 193–6). These rocks carry a few small phenocrysts of bytownite, frequently

worn and corroded, with prisms of enstatite and augite, in a groundmass of labradorite laths, augite, and iron-ore granules. The base, which may represent a devitrified glass, now consists of an ill-defined, turbid, untwinned, felspathic substance and quartz, which carries numerous microlites of iron-ores. The rock is fully described in the above-cited paper. A N.N.W. dyke with similar characters occurs in the Church Burn at Corrie.

The dykes of the cumbraite facies, therefore, are distributed in a narrow band running S.S.E. from the Cowal peninsula, through the Great Cumbrae, down into central Ayrshire; and thence with a more south-easterly trend through the Muirkirk district towards the Scottish border. South of the border they give place to dykes which are regarded as basic varieties of inninmorite (Cleveland dyke) and the Brunton type of tholeiite (Anderson & Radley, 1916, p. 209). The cumbraites appear to belong to the regional or solitary dykes of Sir A. Geikie; and this may be the reason for their non-appearance in Arran, where the dykes are local and connected with the Arran centre of Tertiary eruption.

(*To be concluded in the August Number.*)

NOTICES OF MEMOIRS.

I.—The Oilfields of Egypt.[1]

BETWEEN the Sinai Mountains and the Red Sea Hills lies a depressed area bounded by faults and traversed by three hill-ranges, the Esh Mellaha, Zeit, and Araba Hills, which are separated from each other and from the main ranges by three plains and the Gulf of Suez. All these features trend approximately north-west and south-east. The breadth of the sunken tract is on the average 100 kilometres, of which the Gulf occupies about one-fourth.

Although petroleum has only been found in quantity in the peninsula of Jemsa, near the entrance to the Gulf, and at Rarquada[2] about 50 kilometres to the south-east of Jemsa, near the shore of the Red Sea, the whole of the area, together with a narrow strip on the shore of the Red Sea, extending as far as Ras Benas, is characterized by great geological similarity, and may be referred to as the oilfield region; but the district more especially dealt with in this report lies between 27° 10′ and 28° 10′ North lat., and 33° and 33° 50′ East long. A coloured geological map of this area and a plate of ten horizontal sections accompany the Report. During the progress of the work, extending over several years, the author examined some of the Roumanian oilfields under the guidance of Professor Mrazec, who subsequently visited Egypt and to whom we are mainly indebted for the horizontal sections.

Those portions of the Report which deal with the tectonic features of the oilfield region have recently been summarized by the author

[1] Report on the Oilfields Region of Egypt, by W. F. Hume, D.Sc., A.R.S.M., F.R.S.E., Director Geological Survey of Egypt. pp. viii and 103, with a geological map (1 : 150,000) from surveys by John Ball, Ph.D., D.Sc., F.G.S., 23 plates, and 9 text-figures. Cairo: Government Press, 1916. Price 30 P.T.

[2] Rarquada is opposite Gefatin Island

himself in the GEOLOGICAL MAGAZINE,[1] so that it will be unnecessary in this notice to go into that branch of the subject in any detail.

In dealing with the succession of deposits the author follows the Lyellian method, beginning with the most recent. In this brief summary we will reverse the process, though we do not wish to suggest that this method should have been followed in the Report. The oldest rocks consist of granite and of ancient volcanic and sedimentary rocks, similar to those of the Red Sea Hills and the Sinai Mountains, probably of Archæan, certainly of pre-Carboniferous age. They form the cores of the asymmetric anticlines of the Esh Mellaha, Zeit, and Araba Hills as described by Dr. Hume in the paper already referred to. On the old floor formed of these rocks were deposited Nubian Sandstone, Cretaceous and Eocene strata. The succession is the same as that occurring on the western side of the Red Sea Hills and in Sinai, except that in the latter locality flat-bedded Carboniferous strata intervene between the old floor and the Nubian Sandstone.[2] The Cretaceous and Eocene rocks are seen only in the hill ranges where their thickness is often greatly reduced by folding. Their presence confirms the view generally held that these rocks were originally continuous over the whole area.

The Miocene rocks which follow rest on any of the underlying series. Thus on Shadwan Island they rest on granite and in the Zeit range on Lower Cretaceous strata. In the Esh Mellaha range, some 20 kilometres to the west of the Zeit range, both the uppermost Cretaceous and the Eocene rocks are present. It follows, therefore, that the Gulf of Suez marks the position of the axis of a post-Eocene and pre-Miocene anticline from which the sediment overlying the granite must have been wholly or partially removed by denudation before the Miocene rocks were deposited. We may remark in passing that in other parts of Egypt this interval is represented, to some extent at least, by the so-called petrified forests, the fluvio-marine series of the Fayum, and other deposits of a continental type.

Flint conglomerates and coral reefs occur at the base of the Miocene. In the Zeit range conglomerates, resting on Cretaceous strata, are immediately followed by a dark limestone containing fossils which M. Fourtau has identified with forms "typical of the Lower Miocene (Burdigalian) and of the Lower Helvetian (Lower Middle Miocene)". The limestone is succeeded by an important series of *Globigerina* marls with *Aturia aturi*, *Terebratula miocenica*, and a delicate Pecten fauna. Similar marls have been met with in a boring at Rarquada between 1,169 and 1,181 feet where they are underlaid by a limestone and a flint conglomerate, as in the Zeit range. This boring terminated in sands which Dr. Hume identifies with the Nubian Sandstone. The sands yielded oil. These fossiliferous strata are succeeded by deposits of clay, gypsum often calcareous, dolomitic limestones and salt; their total thickness cannot

[1] "Some Notes on the Post-Eocene and Post-Miocene Movements in the Oilfield Region of Egypt": GEOL. MAG., January, 1917, pp. 5–9. The map illustrating this paper should be referred to.

[2] See review of Dr. Ball's memoir on *The Geography and Geology of West-Central Sinai*, GEOL. MAG., February, 1917.

be less than 3,000 and may be as much as 6,000 feet. Above this great saliferous formation, which is generally unfossiliferous, occur oyster beds containing *Ostræa virleti* and an oyster of the *crassissima* type. Pending a more detailed examination of the palæontological evidence the beds from the flint-conglomerate up to and including the oyster beds are grouped together as being of Plio-Miocene age. They all belong to the Mediterranean area and can be connected up to the north with the Miocene deposits which occur between Suez and Cairo.

The oyster-beds are followed by strata containing the remains of sea-urchins and Pectens now living in the Red Sea and Indian Ocean, together with some forms which are apparently extinct. These deposits are referred to as Plio-Pleistocene. They mark the invasion of what had hitherto been a southward extension of the Mediterranean province by Erythræan forms of life. The plains are largely covered by thick deposits of gravel, derived from the waste of the hills. These are classed as recent, together with a raised beach of corals and molluscs now living in the Red Sea. The beach forms a marked feature on the Zeit and Jemsa coast at an average height of 15 metres.

Let us now consider the great saliferous formation, with which the oil appears to be associated, in greater detail. Gypsum is the most prominent rock at the surface. Salt in thick beds is only known from the borings. The gypsum is interbedded with clays or marls, and in some places, as in the Jemsa peninsula, with dolomitic limestone. Vertical sections of four borings are given. They show remarkable changes within short distances. Bore 11 passed through alternations of gypsum and clays to a depth of about 500 feet; then through thick beds of salt, separated by thin beds of clay, limestone, and gypsum, to a depth of 2,650 feet, where it ended in salt. The total thickness of salt in this section was found to be about 1,900 feet, or 600 metres. Bore 1, which was apparently situated about one kilometre from Bore 11, is represented as being entirely in limestone. It reached a depth of 1,300 feet. The other two bores, less than 300 metres from Bore 1, were in gypsum, with thin beds of clay and limestone. Speaking of the Jemsa oilfield, Dr. Hume says: "Sections have been made of the area so as to include the bore-profiles, but efforts to explain the present conditions either as simple anticlines or synclines have ended in complete failure. There is a provoking horizontality in the strata of the eastern hill of Jemsa, immediately above the oil-belt on the east coast. . . . What we do know is that the Jemsa borings which have yielded profitable oil occupy a long thin band close to the sea, parallel to the general fold movement of the country."

The oil at Jemsa appears to have been obtained from the dolomitic limestone which is porous, and therefore likely to form a good reservoir rock. Fragments of a similar limestone are common on the surface of the gypsum throughout the oilfield region. Dr. Hume suggests that this feature, and also the great thickness of limestone met with in some of the borings, may be due to the removal of gypsum in solution from beds containing both carbonate and sulphate

of lime. Mr. Lucas contributes a chapter on the solubilities of these two substances in water and saline solutions, in which he shows that the relative solubility of gypsum increases up to a certain point as the salinity increases; and Dr. Hume points out that the underground waters at Jemsa have approximately the composition most favourable for the solution of gypsum. There appears to be strong reason for believing that the circulation of water in the saliferous formation has brought about great changes in the nature and distribution of the original materials.

Salt which has been met with in several bores does not occur in one central core as in the Roumanian fields, but is interstratified with shales and gypsum. It is best developed in the minor anticlines, and "Professor Mrazec was strongly impressed with the idea that these strata [the salt-beds] were derived by a leading action from salty clays, similar to those well developed at the surface, whereas beds of salt have never been noted on the large scale in the above ground observations". Dr. Hume suggests that the saliferous deposits were formed in a slowly sinking area into which sea-water could gain access, that the evaporation over this area was sufficient to cause the precipitation of gypsum and salt, and that while this was going on streams were bringing down clay and calcareous matter from the surrounding land.

The similarity in many respects of this formation to that of the Roumanian oilfields is referred to. May we not extend the correlation? *Aturia aturi* is a characteristic fossil of the "Schlier" which, according to Suess[1] and others, includes the Carpathian salt-beds, and probably also those of Armenia and Azerbigan, of the Iranian tableland as far as Khorasan, of the valley of the Tigris, and of the coast of the Persian Gulf. Doubt may exist as to the precise correlation of all these saliferous formations which, as Suess says, "afford us the spectacle of a great expiring sea"; but it seems clear that, both as regards age and mode of formation, the deposits of the Egyptian oilfield are closely allied to them; and it is with them that some of the most important oilfields of the world are intimately associated.

No definite opinion is expressed as to the origin of the petroleum, but the porous limestone (Jemsa) and the Nubian Sandstone (Rarquada) are regarded as reservoir rocks. Indications of oil are most conspicuous on both sides of the Gulf of Suez, and as the overfolding of the anticlines is directed towards the Gulf, it is suggested that the post-Miocene stresses probably reached their greatest intensity in this region, and may therefore have forced the oil into any rocks in the neighbourhood capable of containing it.

No detailed records of bores are given, except the four at Jemsa, and no statistics of production. It is to be regretted that so much secrecy should be considered necessary by those engaged in controlling and developing the economical resources of a country, and very doubtful whether it is not carried much further than is required for commercial purposes. Rivals generally find out sufficient for their purpose, and the progress of science is, therefore, often unnecessarily

[1] *Face of the Earth*, vol. i, p. 309, English translation.

retarded. Moreover, valuable information may be, and often is, lost. Wherever Governments grant facilities for exploration by deep bores they should see that accurate records are kept and made public after a reasonable lapse of time.

The two outstanding features which sharply differentiate the oilfield region from the plateau regions of Sinai and Egypt are the presence (1) of a thick series of Miocene rocks belonging to the Mediterranean area, and (2) of sharp folding due to tangential pressure. We repeat the question that we put in reviewing Dr. Ball's memoir on West Central Sinai. Did the Miocene sea advance over a planed down surface of the older rocks? It was at one time supposed that some at least of the faulting in the region between Suez and Cairo was of post-Eocene and pre-Miocene date, and that Miocene rocks had been deposited against "horsts" of Eocene limestone. That view was disproved by Barron,[1] who showed that they were superposed upon, not apposed against, the Eocene strata, and that no evidence of pre-Miocene faulting was to be found in that district. Now Dr. Hume comes forward with evidence that the Miocene rocks of the oilfield region were formed over the denuded arch of the great post-Eocene fold whose axis coincided approximately with what is now the Gulf of Suez. Although we are not able to define with precision the boundaries of this southward extension of the Miocene sea there is some evidence to show that it did not extend far beyond the faults which bound the sunken tract on the east and on the west, and, therefore, as Dr. Hume points out, that it found a gulf agreeing approximately in position and direction with this tract and its continuation in the Red Sea trough. But in any case there must have been a considerable geocratic movement in post-Miocene times, for Dr. Ball has shown that Miocene rocks occur at a height of 642 metres on Sarbut el Gamal[2] in West Central Sinai, and has estimated the throw of the post-Miocene faults in that region at about 2,000 metres. Even allowing for the possibility that this may be an over-estimate, there seems no escape from the conclusion that the oilfield region owes its position largely to subsidence along faults of later date than the Miocene rocks of the district. But we must await the more precise determination of the palæontological horizons before attempting to correlate the physical history of the oilfield region with that of the Mediterranean area to which it belonged until it was invaded by the Erythræan fauna in comparatively recent times.

It is interesting to compare the views of Suess as to the structure of the district with those set forth in this memoir and in other publications of the Egyptian Geological Survey. In his chapter on the Great Desert Plateau Suess shows that flat-bedding in the Cretaceous and Tertiary rocks is the characteristic feature of large portions of North Africa south of the Atlas range, of the Sinai peninsula, of North and South Arabia, of Palestine and Syria, and that the same feature probably extends as far east as the Persian

[1] *The Topography and Geology of the District between Cairo and Suez*, Cairo, 1907, p. 55.

[2] See GEOL. MAG., February, 1917, p. 83.

Gulf. The only post-Tertiary movements that he recognizes over this vast area, extending eastwards from the Atlantic Ocean for some 3,000 miles, are "in the form of subsidence, particularly as great trough-subsidences, which are here and there associated with flexure of the edges. On the other hand, tangential movement and folding are entirely absent, at least as far as we can judge at present". This view can no longer be maintained if we are to understand by "subsidence" movements along normal faults. Flat-bedding, so far as the eye can judge, certainly is the dominant feature in the Egyptian portion of the Nile Valley, in the Oases, and in Sinai. But, as Dr. Hume has pointed out,[1] the V-shaped outcrops on the geological map of Egypt require the assumption of a broad syncline whose axis dips slightly to the north, while the relations of the Cretaceous and Eocene rocks to the Red Sea Hills and Sinai Mountains indicate the presence of a complementary anticline to the east. Thus folds of great amplitude certainly occur in this portion of the desert plateau, reminding one of the swell of the ocean which is often felt far away from the storm centre which produces it. Now Dr. Hume shows us that sharp folding due to tangential pressure is also present. But this alone would probably not have led Suess to modify his general view. He would doubtless have regarded it as connected with a trough subsidence and therefore of only local importance.

The Report is well illustrated by photographs of scenery and figures of the more characteristic fossils which are briefly described by M. Fourtau in a special chapter. It does not profess to be final. The map is said to be provisional and research is still going on. We await with interest the communications which are to follow, and conclude by wishing success to those who are engaged in developing the Egyptian oilfield, to whom we are indebted, both directly and indirectly, for so much geological information about this most interesting region.

J. J. H. T.

II.—The Conchological Features of the Lenham Sandstones of Kent, and their stratigraphical importance. By R. Bullen Newton, F.G.S., of the British Museum (Natural History).

Part II.

Conclusions.

WE gather from the previous literature on this subject that the majority of investigators have agreed that the Lenham Beds are equivalent to the Diestian deposits of Belgium, which have been generally recognized by geologists as belonging to the base of the Pliocene system, on account of the shell remains exhibiting a marked Miocene facies with many species identical or related to southern or Mediterranean forms. The Miocene aspect of the Lenham fauna is very pronounced, as out of the seventy-seven conchological species that have been determined in the present work, forty-seven, or sixty per cent, date their origin from the Vindobonian

[1] Explanatory notes to accompany the geological map of Egypt.

(Helvetian–Tortonian) stage, which represents the middle part of that epoch in such countries as Germany, Italy, France (S.), Holland, Denmark, and Austria (Vienna Basin). Again, twenty-six of the Lenham species occur as well in the Redonian beds of Gourbesville, Normandy, which are either of Vindobonian or Messinian age, and therefore Miocene. These Gourbesville deposits are of peculiar interest. They were originally discovered by Vasseur,[1] and ascribed to Pliocene or Red Crag times, having been more critically studied since by M. G. F. Dollfus,[2] who in 1880 regarded them as of similar age, although subsequently determining them as belonging to his[3] "Etage, Rédonien", which in explanation was stated to be neither Helvetian nor Plaisancian, but equivalent in time to the Tortonian stage of the Miocene, notwithstanding that he had previously paralleled this new horizon with the Anversian Beds of Belgium.[4] The Redonian fauna was considered to be related to the Gedgravian (Coralline Crag) of England.

About twenty of the Lenham shells, including *Anadara diluvii*, occur in the Upper and Middle Miocene of Holland, and a rather smaller number of species in the same horizons of Denmark, as determined by Molengraaff and Van Waterschoot Van der Gracht[5] for Holland and by Ravn[6] for Denmark. The Pelecypod, *Anadara diluvii*, is of frequent occurrence in the Lenham Beds, and although unknown in the Diestian of Belgium, it is found in the Bolderian (= Tortonian) and Anversian (= Messinian) of that country, as well as in the Vindobonian of Germany, France, Austria, and Italy, and in the Plaisancian deposits of Italy and France; its only British occurrence from the Lenham sandstones was first recorded by Mr. Reid. The Lenham fauna presents an interesting resemblance to that of the Upper Miocene of North Germany (Reinbeck and Holstein), described by Zimmermann[7] and Gottsche,[8] and regarded as Messinian or the latest stage of the Miocene period, a formation-term introduced by Mayer-Eymar,[9] to include Pontian–Sarmatian, Zanclean, and Miocene of other authors. The North German Miocene deposits contain twenty-five species of Mollusca which are also found in the Lenham Beds, among them being *Streptochetus sexcostatus*, *Zaria subangulata*, *Tellina benedeni*, *Papillicardium papillosum*, etc.

Speaking further of this Miocene facies of the fauna, it may be observed that *Drillia obeliscus* and *Clavatula jouanneti* are first known in Burdigalian times, whereas *Margaritifera phalænacea* commenced its career in the Aquitanian stage, which forms the basal or oldest

[1] Bull. Soc. Géol. France, ser. III, vol. vii, p. 741, 1879.
[2] Bull. Soc. Géol. Normandie, 1880.
[3] Assoc. Française-Cherbourg, 1905, published 1906, pp. 358–70.
[4] Bull. Soc. Géol. France, ser. IV, vol. iii, p. 258, 1903.
[5] "Niederlande": Handb. Region. Geol., vol. i, pt. iii, p. 53, 1913.
[6] "Molluskfaunaen I Jyllands Tertiaeratlejringer, etc.": Mus. Min. Géol. Univ. Copenhague: Paléontologiques, No. 7, 1907 (plates and text).
[7] "Ueber der Schichten der Tertiärformation welche bei Reinbeck durch die Hamburg, etc.": Amtl. Ber. Deutsch. Nat. Aerz. Kiel (1846), 1847, pp. 232–4.
[8] Die Mollusken-Fauna des Holsteiner Gesteins": Abhandl. Geb. Nat. Ver. Hamburg, vol. x, No. 8, pp. 14, 1887.
[9] *Cat. Syst. Foss. Tert. Mus. Zurich*, 1867, pt. ii, p. 13.

division of the Miocene formation. The following Gastropods may also be referred to as dating from the Vindobonian stage of the Miocene; *Streptochetus sexcostatus*, also Messinian and Anversian; *Bonellitia serrata*, ranging into the Italian Plaisancian; *Terebra acuminata*, occurring also in the Messinian of North Germany, the Anversian of Belgium, and in the Plaisancian and Astian beds of Italy; *Maculopeplum lamberti*, recorded as well from the Redonian of France, the Diestian and Scaldisian of Belgium, the Box-stones and the Coralline and Red Crags of England; and *Ficus reticulata* known also from the Redonian of France, the Messinian of North Germany, the Bolderian, Anversian, and Diestian of Belgium, Box-stones, Lenham Beds, and Coralline Crag of Britain, Plaisancian and Astian of France and Italy, and belonging also to recent seas. Among the chief Pelecypods similarly originating in Vindobonian times are: *Glans senilis*, known also in the Redonian, Scaldisian, and Coralline Crag; *Arcopagia ventricosa*, also Plaisancian and Astian; *Tellina benedeni*, Messinian and from Bolderian to Scaldisian; *Plagiocardium hirsutum*, Plaisancian and Astian; *Astarte basteroti*, Redonian, Diestian, and Scaldisian; *Papillicardium papillosum*, Messinian, Redonian, St. Erth Beds, Plaisancian and Astian to recent seas; *Cyprina rustica*, Messinian, Anversian to Scaldisian, Box-stones, and Coralline Crag; *Cyrtodaria angusta*, Messinian, Bolderian to Scaldisian, Box-stones, and Coralline Crag; and *Panopæa menardi*, Anversian, Messinian, Box-stones, Coralline and Red Crags.

The only representative of the Brachiopod group of shells is *Terebratula perforata*, which ranges through the Redonian of France, Bolderian to Scaldisian of Belgium, and the Coralline and Red Crags of Britain. With the exception of *Ficus reticulata* and *Papillicardium papillosum*, which exist in present seas, the species thus enumerated are extinct. Several of the Lenham species occur in the Bolderian and Anversian beds of Belgium, the latter according to M. Dollfus[1] being Vindobonian, and equivalent to his Redonian stage, although attributed by Renevier[2] to the later Pontian (= Messinian) division of the Miocene. The Anversian and Diestian occurrences represent 34 and 30 species respectively, Box-stones 12, St. Erth 15, and the Coralline Crag 50. It has been urged by Mr. Harmer that the Coralline Crag fauna is younger than that occurring in the Lenham deposits because several of the older shells found there and that have been previously alluded to are absent in the Coralline Crag beds, a fact more or less accurate, although some important forms do occur in those deposits, such, for instance, as *Margaritifera phalænacea*, *Glans senilis*, *Cyrtodaria angusta*, *Panopæa menardi*, *Terebratula perforata*, etc.

All these facts seem to suggest that the Lenham and Coralline Crag faunas, although showing certain differences of detail, are, nevertheless, to be regarded as presenting a close relationship, and therefore to be considered as of approximately the same age. Marked affinities are also noticeable in the molluscan faunas of the Coralline

[1] Bull. Soc. Géol. France, ser. iv, vol. iii, pp. 256-60, 1903.

[2] "Chronographie Géol.—Text Explicatif": Comp. Rend. Cong. Géol. Internat. (1894), 1897, p. 597.

Crag and the Diestian beds of Belgium. This is apparent from Mr. Harmer's list of the Diestian species (Quart. Journ. Geol. Soc., 1898, vol. liv, p. 317), in which, out of rather more than seventy forms enumerated, nearly all are stated to occur in the Coralline Crag.

A considerable proportion of the Anversian species of Belgium, as listed by M. Van den Broeck (Ann. Soc. Mal. Belgique, 1874, vol. ix, pp. 118–121), likewise occur in the Coralline Crag, as out of a list of 175 species 80 are recognized as being found in that formation.

The following table shows the numerical representation of the seventy-seven Lenham species occurring in the principal formations :—

Recent	40 species.
Post-Pliocene	23 ,,
Astian	36 ,,
Plaisancian	40 ,,
Scaldisian	44 ,,
Norwich Crag	12 ,,
Red Crag	48 ,,
(probably derived from Coralline Crag).	
Coralline Crag	51 ,,
St. Erth	16 ,,
Box-stones	13 ,,
Diestian	30 ,,
Anversian	34 ,,
Messinian	25 ,,
Bolderian	17 ,,
Redonian (Tortonian)	26 ,,
Vindobonian (Helvetian–Tortonian)	47 ,,

The so-called Older Pliocene beds of Mr. Reid's memoir are characterized by shells with a southern facies indicating warmer climatic conditions than prevailed in the Red Crag period, when boreal and Arctic species were largely predominant. The East Anglian Box-stone deposits have been regarded by Mr. Harmer[1] as the probable equivalent in time of the Waenrode Beds of Belgium, which Van den Broeck[2] has considered to be of Bolderian age and therefore Miocene. In this connexion it is interesting to note that the Box-stone beds have been quite recently regarded as Miocene by Mr. Reid.[3]

Sir Ray Lankester[4] determined some Proboscidean remains from those beds as a new species of *Mastodon*, although subsequently recognizing them as a variety of *M. angustidens* of Cuvier,[5] being further of opinion that they were older than the Diestian of Belgium. It is well known that Cuvier's species characterizes the older Vindobonian beds of France, and is frequently found in the ossiferous deposits of Sansan. When the Box-stone Mollusca are more studied, such an age as is here indicated will probably be more conclusively proved; in the meantime the evidence is in favour of those deposits being older than the Lenham Sandstones. The St. Erth deposits of Cornwall were originally described by Searles Wood[6] as

[1] Quart. Journ. Geol. Soc., vol. lvi, p. 708, 1900.
[2] Ann. Soc. R. Mal. Belgique, vol. xix, pp. lvi–lxvi, 1884.
[3] Mededeel. Rijks. Delfst., 1915, No. 6, p. 9.
[4] Quart. Journ. Geol. Soc., vol. xxvi, pp. 507–9, 1870.
[5] GEOL. MAG., 1899, p. 292.
[6] Quart. Journ. Geol. Soc., vol. xli, pp. 65–73, 1885.

of Red Crag age, although he observed that "the character of the mollusca, as a whole, is essentially southern, no peculiarly Arctic shell having as yet occurred".

The fauna was more particularly described by Professor Kendall and R. G. Bell[1] in the following year and again referred to as contemporary with that of the Red Crag, a result contrary to the views of Mr. Reid, who claimed a greater age. Since that discussion Mr. Alfred Bell[2] has published a paper on the St. Erth Mollusca and regarded their age as Mio-Pliocene or Messinian, a somewhat similar horizon having already been partially suggested by Gwyn Jeffreys,[3] who stated: "He was not clear whether the St. Erth deposit was of Older Pliocene or possibly of Upper Miocene age." In the same paper Mr. A. Bell placed upon record an important opinion he had received from M. Dollfus, which reads as follows: "You have in St. Erth exactly the same Pliocene fauna as we have at Gourbesville in the Cotentin," a statement more or less confirming the previous researches of Mr. Reid (1890), who had acknowledged the necessity of a strict comparison between the molluscan species of Gourbesville and those of the St. Erth deposits, as the fossils from the former locality "point to conditions very similar to those indicated by the shells from St. Erth". The Gourbesville fauna, however, as previously mentioned, is now considered to be of Miocene age (Tortonian or Messinian). About fifty per cent of the Lenham shells are extinct species, a somewhat similar percentage marks the Box-stone fauna (according to a calculation made from Mr. A. Bell's memoir in Journ. Ipswich Field Club, vol. iii, pp. 7, 8, 1911), and Mr. Reid (Survey Memoir, 1900, p. 64) has stated that the Coralline Crag and St. Erth deposits contain each about forty per cent of extinct shells. It will be observed that there is a similarity running through these percentages of extinct forms, which appears to furnish satisfactory evidence for regarding the four stages of Mr. Reid's "Older Pliocene" group as of the same approximate geological age, although the Box-stones, as before explained, may be somewhat older.

From the foregoing details of the different faunas involved in this discussion, it is certain that many of the species had their origin in Miocene times. There is good reason for recognizing the St. Erth shells as of Miocene age, because of their relationship to species characterizing the French Redonian. Similarly, the Box-stone fossils would belong to the same period, as their affinities are with those of the Bolderian of Belgium, which is generally regarded as Tortonian or Upper Vindobonian.

Lastly, the Lenham fauna with its strong Vindobonian and Coralline Crag facies should also be placed in the Miocene, and in consideration of its relationship to that characterizing the Upper Miocene deposits of Northern Germany and the Anversian beds of Belgium, I would recognize it as belonging to the latest or Messinian stage of the Miocene, which is synonymous with the term Mio-Pliocene. The stratigraphical name of Mio-Pliocene was introduced into Belgian

[1] Quart. Journ. Geol. Soc., vol. xlii, pp. 201–14, 1886.
[2] Trans. Roy. Geol. Soc. Cornwall, vol. xii, p. 133, 1898.
[3] Quart. Journ. Geol. Soc., vol. xli, p. 72, 1885.

geology by Mourlon,[1] who regarded it as including Lyell's "Upper Miocene" and Dumont's "Pliocène Diestien". It was recognized as comprising two divisions or zones, the first characterized by *Panopæa menardi*, and the second by *Glycymeris* [*Pectunculus*] *pilosa*, both of which are now included in the Anversian stage, or "Crag Noir", of the Belgian Miocene, which is developed at Edeghem and Antwerp. These two Pelecypods occur in the Vindobonian strata of Europe, *P. menardi* being found as well in the Lenham Beds, Box-stones, and Coralline Crag beds, whereas *Glycymeris pilosa* is found present in the same horizons, being likewise a member of the St. Erth fauna. Although acknowledging certain differences in the faunas of these Upper Tertiary horizons, which may be probably accounted for by different conditions of environment, no great disparity of time need be allowed for in considering their geological age. I am induced, therefore, from a knowledge of their conchology, to regard the Coralline Crag,[2] the St. Erth Beds, and the Lenham Beds of Britain, together with the Diestian and the Anversian of Belgium, as of Upper Miocene age, and belonging to the stage Messinian or Mio-Pliocene, while the Box-stones, or Nodule beds of East Anglia, I should consider as referable to the Vindobonian division of the Middle Miocene.

In accordance with these views, therefore, the following synopsis of the various geological horizons referred to is now proposed:—

Recent		British and Mediterranean Seas.
Post-Pliocene	Glacial, etc.	Britain.
Pliocene	Norwich Crag	Britain.
	Red Crag (= Astian of Italy and Scaldisian of Belgium)	Britain.
Upper Miocene or Messinian (= Pontian or Mio-Pliocene)	Coralline Crag	Belgium.
	Diestian	Belgium.
	St. Erth Beds (Cornwall)	Britain.
	Lenham Sandstones	Britain.
	Anversian (= "Crag Noir" of Edeghem and Antwerp)	Belgium.
	Upper Miocene	Germany (N.).
Middle Miocene (= Vindobonian)	Redonian (= Tortonian or Anversian)	France (N.W.).
	Box-stones (= Bolderian of Belgium)	Britain.
	Helvetian–Tortonian	Italy, Vienna Basin, Holland, Denmark, etc.
Lower Miocene	Burdigalian	France (S.W.).
	Aquitanian	Italy.

[1] *Géologie de la Belgique*, vol. i, p. 261, 1880.

[2] The foraminiferal evidence, also, lends support to the view that the Coralline Crag is of older age than has yet been accepted. According to the Monograph on the Crag Foraminifera by Jones, Burrows, and others (Palæontographical Society, 1897, p. 369) the following species are recorded from the Coralline Crag of Sudbourne: *Nummulina planulata*, *Amphistegina vulgaris*, *Operculina complanata*, and *Orbitoides aspera*, formerly determined as *O. faujasi*. These are said to be "derived from earlier beds", although from a recent examination of the specimens, which are in the Geological Department of the British Museum, they present the appearance of having been found in situ. However, the so-called *Nummulina* might indicate an Eocene or Oligocene horizon, but the other organisms are characteristically Miocene, especially when it may be stated that in *Orbitoides aspera*, after

Lastly, I may mention that in 1907 I was favoured with a visit from the late Professor Dr. Gottsche, Director of the Hamburg Museum, and one of the chief authorities on the molluscan fauna of the North German Miocene deposits, for the purpose of examining the Lenham Collection of the Museum of Practical Geology, which was then in my keeping at the British Museum; he was specially interested in some specimens referred to in Mr. Reid's memoir as an elongated variety of *Triton heptagonum* (?), being confident that they represented Beyrich's *Fusus sexcostatus*, a characteristic fossil of the Upper Miocene formation of North Germany. He was further of opinion that the Lenham Beds were older than had hitherto been supposed, and he considered that they should be referred to the Miocene period.

REVIEWS.

1.—Some Problems in South African Geology. By P. A. Wagner. Proc. Geol. Soc. South Africa, 1917, pp. xix–xxxix.

In his Presidential Address to the Geological Society of South Africa for 1917 Mr. P. A. Wagner dealt at some length with four outstanding problems of the geology of that country, namely, the origin of the gold-reefs of the Rand, the genesis of the diamond, alteration of diamonds after their formation, and the nature of the famous salt pan near Pretoria. On each of these he had something of interest to say. An excellent summary is given of recent views as to the source of the gold in the Banket. Dr. Mellor has recently brought forward evidence in favour of the "placer" theory, founded largely on the actual distribution of the gold in the conglomerates. It is found by assays that the gold is richest where the pebbles are largest, and it is therefore argued that the gold was deposited by the strong currents that brought the large pebbles, the weaker currents that could bring only the finer sand not being competent to carry the heavier grains of gold. Nevertheless, the actual character of the particles of gold indicates recrystallization in place. Mr. Wagner dissents from Dr. Mellor's view that the quartzites and conglomerates were deltaic deposits and regards them as having been formed on beaches in a subsiding area.

The author considers kimberlite as the hypabyssal or volcanic form of a peridotite magma which he believes to underlie the granitic and other rocks at a great depth, and he regards the diamonds as original constituents of this magma, brought up, often in a fragmental form, during extrusion. He also gives some facts of great interest as to the possible effect of radio-activity or other agencies on diamonds after they reached their present position. This subject, however, appears to be of a very speculative nature, and much work is obviously required.

The salt pan on the farm Zoutpan, 25 miles N.N.W. of Pretoria, now gives rise to a considerable industry. The pan itself is a most

careful rubbing down of the horizontal surface on the median plane of the figured example, there is exposed a series of minute chamberlets of squarish or hexagonal outline which can only belong to the Miocene genus *Lepidocyclina*.

remarkable structure, and has been described by Cohen, Kynaston, and Hatch & Corstorphine. It presents the appearance of a crater lake, dry in winter, but until disturbed by working it contained a brown brine in the rainy season. It is surrounded by a rim of granite some 200 feet high, with a gentle slope on the outside and a steep slope on the inside. The rim of granite is a most remarkable feature. The floor of the pan has been pierced by borings to a depth of 1,100 feet, and it is found to be composed of alternate layers of salt and mud. The salts have on the average very nearly the theoretical composition of trona, $Na_2CO_3 . NaHCO_3 . 2H_2O$, with some sodium chloride but very little sulphate. The evidence as to the origin of these salt deposits is scanty and not very satisfactory; they may be derived from the decomposition of the perthitic felspar of the granite or from underground waters of either volcanic or meteoric origin. Opinions differ as to the origin of the pan itself. It may be due to the impact of a large meteorite, like Coon Butte in Arizona, or it may be a volcanic pipe like the Maare of the Eifel or Geitsi Gubib in South-West Africa; the latter appears the more probable, although the upward bulging of solid granite in the form of a dome or even of a ring seems rather difficult of belief. It is evident that the last word has not yet been said on the origin of structures of this and related types.

R. H. Rastall.

II.—Analyses of Western Australian Rocks, Meteorites, and Natural Waters. By Edward S. Simpson, B.E., B.Sc., F.C.S. Bull. No. 67, Western Australia Geological Survey.

THIS bulletin is a collection of the records of all the analyses performed in the Government laboratory between the years 1897 and 1916. It deals with rocks, meteorites, and natural waters.

The rocks are divided into igneous, metamorphic, and sedimentary, and these divisions are subdivided according to silica percentage to facilitate reference to the lists. The compiler states that these analyses are not to be taken as a quantitative representation of the rock-types of Western Australia, but that they deal, as is natural, with the types of greater interest to the miner and the agriculturist. In addition to the analyses of the igneous rocks, Brögger–Hobbs diagrams are given of many types, and in most cases the "mode" and "norm" are given, and the rock is classified according to the quantitative system.

Most of the rocks fall into the described groups, but two of them, an amphibolite and a gabbro, fall inside no known group, and have a sufficiently definite composition to warrant placing them in a new group (IV, i, i, 3, 2), for which the name Murchisonose is proposed.

In the analyses of the sedimentary rocks two points of interest present themselves. The first is the composition of the dune sands from Dongara, which consist principally of foraminifera, calcareous algæ, and powdered mollusca, and have at times as little as 3·8 per cent of silica, being almost entirely made up of calcareous matter. The other point of interest is the excessive humidity of the

bituminous coals, which often contain as much as 23 per cent of moisture. Among the rocks there is a curious series of dyke or vein rocks of unknown origin called "hæmatite quartz rocks", which are placed in a class by themselves. They consist principally of hæmatite and chalcedony, and have an iron content of 47 to 54 per cent of Fe_2O_3, which occasionally rises as high as 92 per cent in the hæmatite rocks. In the section on meteorites twelve undoubted siderites of nickeliferous iron are described, the large numbers of doubtful obsidianites which have been found in the colony being neglected. The natural waters analysed are drawn from a variety of sources—artesian wells, surface wells, and mines. They are used for drinking water, steam-raising, irrigation, stamp batteries, and the cyanide process. The amount of solid matter is often very high, sometimes reaching more than 15 per cent, which is principally sodium chloride. It is interesting to note that in the surface waters of one district there is a considerable quantity of sodium nitrate, amounting to 19 parts of nitrogen to the million. This is attributed to a train of favourable circumstances, there being great bacterial activity in the soil, low rainfall, and a dominant vegetation of a leguminous plant called "mulga".

W. H. Wilcockson.

III.—British and Foreign Marbles and other Ornamental Stones. By John Watson. Cambridge University Press, 1916. 5*s*. net.

THIS descriptive catalogue is a companion volume to the same author's well-known *Building Stones*, and it shows the same scholarship and regard for accuracy that characterized the earlier catalogue. The rocks described include (besides marbles) onyx marbles, malachite, alabaster, serpentine, and jade, as well as other less common ornamental stones. The work will appeal very strongly to the architect, and to the geologist who is interested in the application of rocks to decorative purposes.

IV.—The Etchegoin Pliocene of Middle California. By Jorgen O. Nomland. University of California Publications, Bulletin of the Department of Geology, vol. x, No. 14, pp. 191–254, pls. vi–xii, 2 text-figures. Issued April 19, 1917.

THIS memoir treats very exhaustively of the Etchegoin group of rocks and its fauna as developed in the Coalinga District of Middle California, which is considered to be of Pliocene age, although mapped as Upper Miocene by Ralph Arnold and F. M. Anderson. The author regards the vertebrate evidence as confirmation of this horizon, Professor J. C. Merriam having recently described from these beds such genera as *Pliohippus*, *Neohipparion*, *Mastodon*, etc. Faunal lists are drawn up of the marine invertebrates showing a strong resemblance to those of the Jacalitos formation, which, although hitherto kept distinct, may now, in the author's opinion, be united to the Etchegoin group. The memoir terminates with descriptions of several new species of Mollusca—seven Pelecypoda and 8 Gasteropoda—and a doubtful *Serpula*, all of which are suitably figured.

V.—Report of the Rugby School Natural History Society for the Year 1916. 1917.

GEOLOGY still maintains an excellent position among the various sections of this Society. In the present Report (pp. 98–100) it is noted that visits were made to Napton Quarry, and that fossils were collected from the *Capricornus* zone of the Lower Lias. Some pits at Nuneaton are also referred to as having yielded Carboniferous ferns and *Calamites*, while marlstone fossils were obtained from Fawsley Park, near Badby. Doubtless the better part of such material will find its way into the School Museum, which already contains good palæontological specimens, those of local interest being perhaps of greatest importance. This Report also informs us that the Rugby School Natural History Society has now been in existence for fifty years, a fact on which we venture to offer our congratulations.

VI.—New Tertiary Insects. By T. W. A. Cockerell. Proc. United States National Museum, vol. lii, pp. 373–84, pl. xxxi, 1917.

THE material described in this paper was obtained from the Eocene (Oil Shales) of Western Colorado, from the Miocene beds of Florissant, Colorado, and from the Oligocene formation of Gurnet Bay, Isle of Wight, belonging to the British Museum, although originally in the collection of the late Rev. P. B. Brodie. The new British forms described include:—**Diptera**: *Riphidia brodiei*, *Mongoma cruciferella*, *Tipula gardneri*, *Bibio gurnetensis*, *B. oligocenus*, *Mesomyites* (new genus) *concinnus*, *Protoscinis* (new genus) *perparvus*. **Thysanoptera**: *Æolothrips brodiei*. **Neuroptera**: *Sisyra* (?) *disrupta*. The new American species determined include:—**Diptera**: *Plecia winchesteri*, from the Eocene (Oil Shales) of Colorado, and *P. explanata*, from the Florissant deposits, the latter formation having also yielded *Acreotrichites* (new genus) *scopulicornis*, *Rhamphomyia hypolitha*, *Urortalis* (new genus) *caudatus*, *Melieria atavina*, and *Anthomyia persepulta*. **Hymenoptera**: *Tæniurites* (new genus) *fortis* and *Heriades priscus*, both from the Florissant Miocene.

VII.—South Australia. Annual Report of the Government Geologist [L. Keith Ward] for 1915. Fol.; pp. 18, with maps and tables. Adelaide, 1916.

THIS report contains information on metallurgical subjects, water supplies, mineral resources, building stones, etc. A very important item of the year's work concerns the discovery of precious opal at Stuart's Range at a place situated 81 miles west by south of Anna Creek Railway Station. The specimens are stated to have been evidently derived from the Desert Sandstone formation which extends across Western Queensland and New South Wales into the northern portion of South Australia. Valuable notes on the building stones, which are regarded as Palæozoic and Tertiary, are set out in a series of tables at the end of the Report.

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 16, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

A lecture on "British Geological Maps as a Record of the Advance of Geology" was delivered by Thomas Sheppard, M.Sc., F.G.S. He observed that geological changes were in many cases indicated on old topographical maps; consequently, very old plans and charts were of use in connexion with geological inquiries, although not strictly geological in character. Some examples of maps, dating from Elizabethan times, were exhibited, and they showed that in the Humber area great changes had taken place: in certain districts large tracts of land had been denuded, and many towns and villages had disappeared; in others, large stretches of reclaimed land marked places where water once stood. So long ago as 1595 writers were familiar with lithological differences in various parts of the country, and in 1683 Martin Lister read to the Royal Society a paper in which he definitely suggested "A Scheme for the Mapping of Soils and Rocks", wherein he mentioned the various kinds of rocks that occurred in Yorkshire; but his scheme was not actually carried out until a century later. Strachey (1719) and Packe (1743) produced some remarkable geological sections and plans.

The first systematic series of maps, illustrating the geological features of the counties, was issued in the Reports of the old Board of Agriculture, and dated from 1793 to 1822. These reports usually contained "soil-maps" of the counties described, upon which chalk, sandstone, limestone, peat, marl, gravel, etc., were shown by colours and shading. William Smith was certainly familiar with these "Agricultural Surveys", and doubtless they provided him with information that assisted him in the preparation of his great map of the geology of England and Wales, issued in 1815.

One of the earliest and most serious attempts to prepare geological maps was by Professor Jameson, who read a paper in 1805 "On Colouring Geognostical Maps" (Wernerian Nat. Hist. Soc., vol. i. published 1811); but the enormous number of complicated signs and symbols that he suggested proved unsuitable for practical purposes, although there were many good features in his colour scheme.

The first strictly geological map (now in the Society's possession) was apparently that made by W. Smith in 1799, showing the geological structure of the Bath District. This had been proved by the lecturer to have been coloured on a plan originally issued in *The New Bath Guide* of 1799. The first geological map of England and Wales was a small one, also by Smith, and it was presented to the Society by "the Father of English Geology" when the first Wollaston Medal was awarded to him in 1831. The lecturer discussed the history of the various maps and sections published by Smith, and described two hitherto unknown maps (of the counties of Durham and Northumberland) by the same author, in the Society's possession. He also exhibited one of the Scarborough district, found whilst he was cataloguing the Society's maps; all trace of this

particular map had been lost for over eighty years. Smith's finest piece of work, his map of the Hackness district, dated 1832, apparently had not been seen by any worker since its publication, and the lecturer explained how he had recently been able to trace two copies. One of them, which was exhibited, he presented to the Society.

In the Society's possession also is an extensive and valuable collection of the maps of Greenough, both published and in manuscript. Among an extraordinary series of coloured maps of England and Wales, and of the British Isles, issued during the middle of the nineteenth century, those by Arrowsmith, Murchison, Walker, Ramsay, Ravenstein, Knipe, Phillips, and Johnston are especially noteworthy.

The Society's collection includes geological maps of Scotland and Ireland, some of great value and historical interest. Of Scotland, the remarkable series by MacCulloch, published and in manuscript, shows that the collection is by far the finest as regards early maps dealing with the geology of the country. A manuscript map of Scotland by Necker is dated 1808 (earlier than Smith's large map of England and Wales), and is undoubtedly the oldest. Among the maps of Ireland there is the fine series by Griffith, which includes a few examples not known by Judd or other writers on the subject.

As examples of privately published maps, those by Sanders of the Bristol Coalfield, Jordan's London District, and Elias Hall's Lancashire area were described. The lecturer concluded by referring to a catalogue of geological maps (other than the Geological Survey publications) which he had in course of preparation. This already contained details of approximately 3,000 maps.

June 6, 1917.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Geology of the Old Radnor District, with special reference to an Algal Development in the Woolhope Limestone." By Edmund Johnston Garwood, Sc.D., F.R.S., F.G.S., and Edith Goodyear, B.Sc.

The district comprises an inlier of Archæan grits and Woolhope Limestone forming an elongated dome bounded by Wenlock Shale. It was regarded by Murchison and the Geological Survey as consisting of Mayhill Sandstone succeeded conformably by Woolhope Limestone, and they attributed the unfossiliferous character of the sandstone and the abnormal facies of the limestone to alteration by igneous intrusions. Dr. Callaway, in 1900, first suggested that the so-called "Mayhill Sandstone" was of Archæan age, and recorded an unconformity at the base of the limestone. The authors confirm Callaway's views, and give evidence for correlating these Archæan rocks with Professor Lapworth's "Bayston Group" of the Longmyndian. The unconformable relation of the limestone to the Archæan is established in several portions of the district; while a study of the Trilobite and Brachiopod fauna of the limestone and included shale confirms the Wenlock age of the deposit. The most interesting fact brought out by a study of the limestone is the

important part played in its formation by the calcareous alga *Solenopora* (of which a new species is described), the deposit constituting by far the most striking development of algal limestone yet recorded from British rocks. The limestone represents a reef facies of the normal Woolhope Limestone, being largely composed of Bryozoa and calcareous Algæ. Corals, although present, play only a subordinate part. The reef appears to have grown round a subsiding peninsula of Archæan rock, which evidently then formed the south-western continuation of the Longmynd range. The same reef facies is also found to occur at Nash Scar, three miles away to the north-east, where it rests on the Upper Llandovery Sandstone. The sudden change to the normal type of Woolhope Limestone at Corton, near Presteign, appears to mark the northern limit of this lagoon phase.

The paper concludes with an account of the movements that have taken place in the district, to which its general Caledonian trend is due.

2. "Correlation of Jurassic Chronology." By S. S. Buckman, F.G.S.

This paper owes its inception to certain discoveries made by the Officers of the Scottish Geological Survey during their investigations of the Jurassic deposits of the Isles of Raasay and Skye. The Ammonites and Brachiopods were sent to the author for examination, and the sequence of faunas which they disclosed necessarily led to comparison with results obtained in other areas—with Yorkshire, on which the author had recently written a palæontological chapter for a Geological Survey memoir, based largely on information and specimens submitted by the Survey; with the Dorset coast, helped by Mr. W. D. Lang's most painstaking work; with other areas within the author's field experience, helped largely by information most freely communicated by Mr. J. W. Tutcher. The results appeared to be so far-reaching that permission was asked of the Director of H.M. Geological Survey to lay before the Society a synopsis of the information obtained through the investigations of Survey Officers; this was kindly accorded, and the present paper is the outcome of research thus originated.

One of the principles utilized in this paper to ascertain or to surmise faunal sequence where precise information is defective, is that of what may be called "faunal dissimilarity"—that is, if the deposits of two neighbouring localities A and B, supposedly isochronous from their sequential position, show differing faunas, it is a reasonable inference that the faunas are not of the same date. Theoretical stratigraphical correlation has usually worked along these lines, but the principle involved has not been recognized by name. Now the principle is utilized, not only in regard to neighbouring localities, but even more widely, with suggestive results.

The paper is chiefly concerned with the Liassic Ages hitherto known as Domerian, Charmouthian, Sinemurian. In all of them there is proposed a considerable increase of the number of faunal horizons indicative of consecutive time-intervals, or hemeræ. In the case of the first no change of name is made; but in regard to

the other two, subdivisions seem necessary, and each is apportioned into three Ages, as follows:—

Proposed Names.	*Old Terms.*
Hiviccian.	
Wessexian.	Charmouthian.
Raasayan.	
Deiran.	
Mercian.	Sinemurian.
Lymian.	

These, with the Domerian, each contain on an average about ten hemeræ, the grouping being controlled by the dominance of ammonite families of phases thereof—thus, Domerian: Age of Amaltheids; Raasayan: Age of Deroceratidæ and Echioceratidæ. It is obvious that, with this increase in the number of hemeræ, the number of local non-sequences is greatly increased. Some comparative diagrams illustrate this.

One of the most interesting discoveries which has resulted, partly from the great thickness of Scottish strata investigated and collected from, partly from comparisons with other areas, is that the so-called "*armatum* Zone" of the English Midlands and that of the Radstock district, of Yorkshire and of the Scottish Isles, are not isochronous, but are separated by a time-interval which corresponds to a thickness of some 300 feet of deposit in the Scottish area. Thus, instead of the simple descending sequence

Deroceras armatum,
Echioceras raricostatum,

there is this sequence ascertained:

An upper *Deroceras* horizon,
An upper *Echioceras* horizon in three distinct stages,
A lower *Deroceras* horizon,
A lower *Echioceras* horizon with some Armatoids;

and even now possibly this is not the end of the complication. This alternation of *Deroceras* and *Echioceras* involves a phenomenon which the author calls "faunal repetition", and it is a reasonable supposition that this is not a solitary case—that is to say, doubt is at once thrown on the contemporaneity of other so-called "zones" where they have been determined in different areas by the presence of certain species of a genus—the species admittedly not the same—or by the alleged presence of a single species on specific determination insufficiently rigid. The cases of zones determined on the *lucus a non lucendo* principle—the strata in correct intermediate position, but with the index zonal species conspicuously absent—seem especially to invite scepticism.

Three appendices are given—one, palæontological, containing descriptions of certain notable species, mostly new; another, historical, containing notes on certain ammonites described and figured by Wright in a paper published some years prior to the issue of his monograph: it affords clues to the interpretation of his species, to the recognition of some of his missing types, to the identity of certain figures in Reynès's monograph, and to the geographical distribution of species—a matter of particular importance

in regard to faunal dissimilarity; the third, geological—a communication by Mr. J. W. Tutcher, embodying his reading of the sequence in the lower part of the Lower Lias carried down to the base of the Hettangian.

OBITUARY.

PROFESSOR ROBERT BELL,

I.S.O., M.D., D.Sc., LL.D., F.R.S., F.G.S.

BORN 1841. DIED JUNE 18, 1917.

PROFESSOR DR. ROBERT BELL, F.R.S. (formerly Chief Geologist of the Geological Survey of Canada, Ottawa), died suddenly on June 18, 1917, at Rathwell, Manitoba. Dr. Bell, who was 76 years of age, joined the Geological Survey of Canada in 1857, and subsequently made extensive topographical and geological surveys in various parts of the Dominion. He acted as Medical Officer, Naturalist, and Geologist combined on several expeditions to Hudson's Bay and Baffin Land. The Bell River, which he surveyed in 1895, was officially named after him. He also made the first surveys of some of the largest lakes in Canada. He was the Canadian correspondent of the Royal Scottish Geographical Society since its foundation.—*Westminster Gazette*, June 20, 1917.

THOMAS McKENNY HUGHES, M.A.,

Trinity College, Cambridge; Professorial Fellow of Clare College, Woodwardian Professor of Geology; F.R.S., F.S.A., F.G.S.; Chev. Ord. SS. Maur. et Lazar. Ital.; Corr. Memb. Soc. Geol. Belg., Soc. Geol. France, Germany, Italy, etc.

BORN DECEMBER, 1832. DIED JUNE 9, 1917.

WE deeply regret to record the death, on June 9, of our friend of fifty years—a frequent contributor to the GEOLOGICAL MAGAZINE—Mr. T. McKenny Hughes, M.A., F.R.S., Woodwardian Professor of Geology in the University of Cambridge, in his 85th year.

A life of Professor Hughes with a very excellent portrait appeared in the GEOLOGICAL MAGAZINE (N.S., Dec. V, Vol. III, No. 1, pp. 1–13, January, 1906).

The following appeared in the *Times*, June 11, 1917 :—

Mr. T. McKenny Hughes "was born at Aberystwith, and was a member of a distinguished family. His grandfather, Sir Thomas McKenny, took a prominent part in Catholic emancipation in Ireland, his father became Bishop of St. Asaph, and one of his brothers is Bishop of Llandaff.

"Hughes was educated at Leamington and Llandovery Colleges, and took his degree at Cambridge in 1857 as a member of Trinity College. In 1860 he was appointed Secretary to the British Consul at Rome, and was left Acting Consul in that City in 1860 and 1861.

In the latter year he joined the Geological Survey of Great Britain and served on it until 1873, when he succeeded Professor Sedgwick as Woodwardian Professor of Geology at Cambridge. At first his survey work lay among the newer rocks of the south-eastern counties, but in 1866 he was transferred to the borders of the Lake District, where he did much important geological work.

"On going to Cambridge his duties as successor to the eminent Sedgwick were far from easy, but his varied attainments enabled him to discharge them with success. At the outset, in addition to the ordinary duties of his Chair, he devoted himself to three tasks which had connexion with his predecessor—namely, the adoption of the Cambrian system as defined by Sedgwick, the writing of the life of that geologist, and the erection of the Memorial Museum which has been built in his honour. The first of these would have reopened an unfruitful controversy, and Hughes wisely discontinued it. In carrying out the second he secured the services of the late Registrar of the University—Mr. J. W. Clark—and 'The Life and Letters of Sedgwick', by Clark and Hughes, appeared in two volumes in 1890. The performance of the third task was long delayed by many disappointments and difficulties, but Hughes had the satisfaction of seeing the completion of the Sedgwick Museum, which was opened by King Edward in 1904.

"During his tenure of the professorship Hughes did much original work in geology and archæology.[1] He was a fluent lecturer, but his most successful work as a teacher was due to his great capacity for arousing enthusiasm among his pupils, and many geologists owe their interest in the science to his efforts. He was elected a Fellow of the Royal Society in 1889, and received the Lyell Medal of the Geological Society in 1891, when he acknowledged the value of his intimate association with Sir Charles Lyell, with whom he made many geological tours during his early years. He was a Professorial Fellow of Clare College, and Chevalier of the Order SS. Maurice et Lazarus (Italy).

"He married, on November 28, 1882, Mary Caroline, daughter of the late Rev. G. F. Weston, Honorary Canon of Carlisle, and had three sons. Mrs. Hughes, who has herself done important geological work, was ever ready to assist her husband in the manifold duties of his professorship [see Mrs. Hughes' Memoir on the Pleistocene Mollusca of Cambridge, GEOL. MAG., 1888, p. 193].

"As Sedgwick was elected Woodwardian Professor in 1818, he and his successor have between them occupied the Chair for ninety-nine years."

LIEUT. HORAS TRISTRAM KENNEDY, B.A., F.G.S.

BORN 1889. KILLED IN ACTION, JUNE 6, 1917.

LIEUT. HORAS T. KENNEDY, F.G.S., who was killed by shell-fire south of Ypres on June 6, was a geologist of great promise on the staff of the Geological Survey of Ireland, which he joined, after open

[1] [For a list of his papers up to 1906 see the life of Professor Hughes, as an "Eminent Living Geologist", GEOL. MAG., 1906, pp. 10–13; the titles of ninety-three separate articles are there recorded.]